

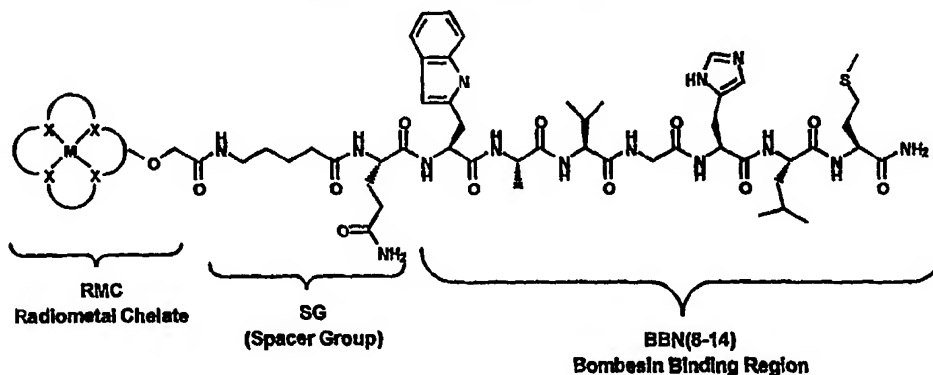


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(54) Title: GASTRIN RECEPTOR-AVID PEPTIDE CONJUGATES

Radiometal Conjugate



Radiometal conjugate of a BBN analogue that has high affinity for GRP receptors.

RMC=Radiometal chelate, where M=^{99m}Tc, ^{186/188}Re, ¹⁰⁵Rh and X=chelating atoms.SG=Spacer group or linker that covalently attaches the chelate to the N-terminal end of the BBN binding region (BBN_{GR})

(57) Abstract

A compound for use as a therapeutic or diagnostic radiopharmaceutical includes a group capable of complexing a medically useful metal attached to a moiety which is capable of binding to a gastrin releasing peptide receptor. A method for treating a subject having a neoplastic disease includes administering to the subject an effective amount of a radiopharmaceutical having a metal chelated with a chelating group attached to a moiety capable of binding to a gastrin releasing peptide receptor expressed on tumor cells with subsequent internalization inside of the cell. A method of forming a therapeutic or diagnostic compound includes reacting a metal synthon with a chelating group covalently linked with a moiety capable of binding a gastrin releasing peptide receptor.

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GASTRIN RECEPTOR-AVID PEPTIDE CONJUGATES

5

TECHNICAL FIELD

This invention relates to radionuclide-labeled compounds useful as radiopharmaceuticals. More particularly, the present invention relates to conjugates of bombesin (BBN) analogues and a metal complexing group which, when complexed to a radionuclide, are useful therapeutic and imaging agents for cancer cells that express gastrin releasing peptide (GRP) receptors.

10

BACKGROUND OF THE INVENTION

Detection and treatment of cancers using

radiopharmaceuticals that selectively target cancers in human patients has

5 been employed for several decades. Unfortunately, only a limited number of site-directed radiopharmaceuticals that exhibit highly specific *in vivo* localization in or near cancer cells are currently in routine use, as being approved by the United States Food and Drug Administration (FDA).

There is a great deal of interest in developing new radioactive drugs due
10 to the emergence of more sophisticated biomolecular carriers that have high affinity and high specificity for *in vivo* targeting of tumors. Several types of agents are being developed and have been investigated including monoclonal antibodies (MAbs), antibody fragments (F_{AB} 's and $(F_{AB})_2$'s), receptor-avid peptides [Bushbaum, 1995; Fischman et al., 1993;
15 Schubiger et al. 1996].

The potential utility of using radiolabeled receptor-avid peptides for producing radiopharmaceuticals is best exemplified by ^{111}In -DTPA-conjugated octreotide (an FDA approved diagnostic imaging
20 agent, Octreoscan®, marketed in the United States. by Mallinckrodt Medical, Inc.) [Lowbertz et al. 1994]. This radiopharmaceutical is an ^{111}In -DTPA conjugate of Octreotide, a small peptide analogue of the

human hormone somatostatin. This drug specifically binds to somatostatin receptors that are over-expressed on neuroendocrine cancers (e.g., carcinoid Ca, neuroblastoma, etc.) as well as others [Krenning et al., 1994]. Since indium-111 (^{111}In) is not the ideal radionuclide for scintigraphic imaging, other somatostatin analogues and other receptor-avid biomolecules that are labeled with $^{99\text{m}}\text{Tc}$ (the optimal radionuclide for diagnostic imaging) are being studied and developed [Eckelman, 1995; Vallabhajosula et al., 1996].

Bombesin (BBN) is a 14 amino acid peptide that is an analogue of human gastrin releasing peptide (GRP) that binds to GRP receptors with high specificity and has an affinity similar to GRP [Davis et al., 1992]. GRP receptors have been shown to be over-expressed or uniquely expressed on several types of cancer cells. Binding of GRP receptor agonists (also autocrine factors) increases the rate of cell division of these cancer cells. For this reason, a great deal of work has been, and is being pursued to develop BBN or GRP analogues that are antagonists [Davis et al., 1992; Hoffken, 1994; Moody et al., 1996; Coy et al., 1988; Cai et al., 1994]. These antagonists are designed to competitively inhibit endogenous GRP binding to GRP receptors and reduce the rate of cancer cell proliferation [Hoffken, 1994]. Treatment of cancers using these antagonists with these non-radioactive peptides requires chronic injection

regimens (e.g., daily, using large quantities of the drug).

In designing an effective receptor-avid radiopharmaceutical for use as a diagnostic or therapeutic agent for cancer, it is important that the drug have appropriate *in vivo* targeting and pharmacokinetic properties [Fritzberg et al., 1992; Eckelman et al., 1993]. For example, it is essential that the radiolabeled receptor-avid peptide have high specific uptake by the cancer cells (e.g., via GRP receptors). In addition, it is necessary that once the radionuclide localizes at a tumor site, it must remain there for an extended time to deliver a highly localized radiation dose to the tumor. In order to achieve sufficiently high specific uptake of radiolabeled BBN analogues in tumors, the binding affinity of promising derivatives must be high (i.e., $K_d \cong 1\text{-}5$ nmolar or less) with prolonged retention of radioactivity [Eckelman et al., 1995; Eckelman, et al., 1993]. Work with ^{125}I -BBN derivatives has shown, however, that for cancer cells that bind the ^{125}I -BBN derivatives (whether they be agonists or antagonists), the radioactivity is either washed off or expelled from the cells (*in vitro*) at a rapid rate [Hoffman et al., 1997]. Thus, these types of derivatives have a low probability of remaining "trapped" at the tumor site (*in vivo*) sufficiently long to be effective therapeutic or diagnostic agents.

Developing radiolabeled peptides that are cleared

efficiently from normal tissues is also an important and especially critical factor for therapeutic agents. When labeling biomolecules (e.g., MAb, F_{AB}'s or peptides) with metallic radionuclides (via a chelate conjugation), a large percentage of the metallic radionuclide (in some chemical form) usually becomes "trapped" in either the kidney or liver parenchyma (i.e., is not excreted into the urine or bile) [Duncan et al., 1997; Mattes, 1995]. For the smaller radiolabeled biomolecules (i.e., peptides or F_{AB}'s), the major route of clearance of activity is through the kidneys which in turn retain high levels of the radioactive metal (i.e., normally > 10-15% of the injected dose) [Duncan et al., 1997]. This presents a major problem that must be overcome in the development of therapeutic agents that incorporate metallic radionuclides, otherwise the radiation dose to the kidneys would be excessive. For example, ¹¹¹In-octreotide, the FDA approved diagnostic agent, exhibits high uptake and retention in kidneys of patients [Eckelman et al., 1995]. Even though the radiation dose to the kidneys is higher than desirable, it is tolerable in that it is a diagnostic radiopharmaceutical (it does not emit alpha- or beta-particles), and the renal dose does not produce observable radiation induced damage to the organ.

20

It has now been found that conjugating BBN derivatives

which are agonists in non-metallated conjugates which exhibit binding affinities to GRP receptors that are either similar to or approximately an order of magnitude lower than the parent BBN derivative. [Li et al., 1996a] These data coupled with our recent results show that it is now possible to add radiometal chelates to BBN analogues, which are agonists, and retain GRP receptor binding affinities that are sufficiently high (i.e., approx. 1-5 nmolar K_d 's) for further development as potential radiopharmaceuticals. These agonist conjugates are transported intracellularly after binding to cell surface GRP receptors and retained inside of the cells for extended time periods. In addition, *in vivo* studies in normal mice have shown that retention of the radioactive metal in the kidneys was low (i.e., <5%) with the majority of the radioactivity excreted into the urine.

According to one aspect of the present invention, there is provided a BBN conjugate consisting of essentially a radio-metal chelate covalently appended to the receptor binding region of BBN [e.g., BBN(8-14)] to form radiolabeled BBN analogues that have high specific binding affinities with GRP receptors. These analogues are retained for long times inside of GRP expressing cancer cells. Furthermore, their clearance from the bloodstream, into the urine with minimal kidney retention, is efficient. Preferably, the radiometals are selected from ^{99m}Tc , $^{186/188}\text{Re}$,

¹⁰⁵Rh, ¹⁵³Sm, ¹⁶⁶Ho, ⁹⁰Y or ¹⁹⁹Au, all of which hold the potential for diagnostic (i.e., ^{99m}Tc) or therapeutic (i.e., ^{186/188}Re, ¹⁰⁵Rh, ¹⁵³Sm, ¹⁶⁶Ho, ⁹⁰Y, and ¹⁹⁹Au) utility in cancer patients [Schubiger et al, 1996; Eckelman, 1995; Troutner, 1978].

5

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided a compound for use as a therapeutic or diagnostic radiopharmaceutical which includes a group which is capable of complexing a metal attached to a moiety capable of binding to a gastrin releasing peptide receptor.

Additionally, in accordance with the present invention, a method for treating a subject having a neoplastic disease which includes the step of administering to the subject an effective amount of a radiopharmaceutical having a metal chelated with a chelating group attached to a moiety capable of binding to a gastrin releasing peptide receptor on a cancer cell, subsequently intracellularly transported and residualized inside the cell, is disclosed.

20

Additionally, in accordance with the present invention, a method of forming a therapeutic or diagnostic compound including the

step of reacting a metal synthon with a chelating group covalently linked with a moiety capable of binding a gastrin releasing peptide receptor is disclosed.

5 **BRIEF DESCRIPTION OF THE DRAWINGS**

Other advantages of the present invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the
10 accompanying drawings wherein:

FIGURE 1 illustrates a radiometal conjugate according to the present invention;

15 FIGURE 2 is an ORTEP drawing of the $\{\text{Rh}[16]\text{aneS}_4\text{-olCl}_2\}^+$, illustrating the crystal structure a Rhodium macrocycle;

FIGURE 3 illustrates a coupling reaction wherein a spacer
20 group is coupled to a bombesin agonist binding moiety;

FIGURE 4 illustrates a coupling reaction for coupling a metal chelate to a peptide;

FIGURE 5 illustrates several iodinated bombesin analogues including their IC_{50} 's;

FIGURE 6 illustrates several tethered bombesin analogues;

FIGURE 7 illustrates several [16]aneS₄ bombesin analogues;

FIGURE 8 is a graph illustrating IC_{50} analysis wherein %I-125-BBN total uptake versus molar concentration of displacing ligand is shown;

15

FIGURE 9 illustrates several Rhodium-[16]aneS₄ bombesin analogues;

FIGURE 10 illustrates an HPLC chromatogram of Rhodium-BBN-37 wherein (A) illustrates $^{105}\text{RhCl}_2\text{-BBN-37}$ and (B) illustrates $\text{RhCl}_2\text{-BBN-37}$;

20

FIGURE 11 is a graph illustrating ^{125}I -Tyr⁴-bombesin internalization efflux from Swiss 3T3 cells;

FIGURE 12 illustrates I-125 bombesin internalization efflux in I-125 free buffer wherein ^{125}I -Tyr⁴-BBN vs. ^{125}I -Lys³-BBN efflux from Swiss 3T3 cells is shown;

FIGURE 13 is a graph illustrating the efflux of ^{105}Rh -BBN-37 from Swiss 3T3 cells;

10

FIGURE 14 illustrates several $^{105}\text{Rhodium}$ bombesin analogues including their IC_{50} 's;

FIGURE 15 is a graph illustrating ^{105}Rh -BBN-61 efflux from Swiss 3T3 cells;

15

FIGURE 16 is a graph illustrating the efflux of ^{105}Rh -BBN-22 vs. ^{105}Rh -BBN-37 from Swiss 3T3 cells;

20

FIGURE 17 are graphs illustrating Pancreatic CA cell binding wherein (A) illustrates the efflux ^{125}I -Tyr⁴-BBN from CF PAC1

cells and (B) illustrates the efflux of ^{105}Rh -BBN-37 from CF PAC1 cells;
and

FIGURE 18 are graphs illustrating Prostate CA cell
5 binding wherein (A) illustrates the efflux of ^{125}I -Tyr⁴-BBN from PC-3
cells and (B) illustrates the efflux of ^{105}Rh -BBN-37 from PC-3 cells.

FIGURE 19 illustrates 5 [16]aneS₄ bombesin analogues.

10 FIGURE 20 illustrates 4 Rhodium-[16]aneS₄ bombesin
analogues.

FIGURE 21 illustrates 3 different N₃S-BFCA conjugates of
BBN(7-14).

15 FIGURE 22 illustrates on HPLC chromatogram of $^{99\text{m}}\text{Tc}$ -
BBN-122.

FIGURE 23 is a graph illustrating $^{99\text{m}}\text{Tc}$ -BBN-122
20 internalization efflux from human prostate cancer cells (PC-3 cells).

FIGURE 24 is a graph illustrating ^{99m}Tc -BBN-122 internalization efflux from human pancreatic tumor cells (CFPAC-1 cells).

5 FIGURE 25 is a graph illustrating ^{99m}Tc -RP-414-BBN-42 retention in PC-3 prostate cancer cells.

FIGURE 26 is a graph illustrating ^{99m}Tc -42 retention in CFPAC-1 pancreatic cancer cells.

10

DETAILED DESCRIPTION OF THE INVENTION

According to the present invention, compounds for use as diagnostic and/or therapeutic radiopharmaceuticals include a group
15 capable of complexing a metal attached to a moiety capable of binding to a gastrin releasing peptide (GRP) receptor as shown in Figure 1. The moiety capable of specific binding to the GRP receptor is a GRP agonist. A GRP agonist would activate or produce response by the GRP receptor upon interaction with the GRP receptor and would be subsequently
20 internalized inside of the cell by endocytosis. In contrast, a GRP antagonist would counteract the effect of an agonist and would not be internalized inside of the cell.

More specifically, the GRP agonist is a compound such as selected amino acid sequences or peptidomimetics which are known to activate the cell following binding with high affinity and selectivity to GRP receptors and that can be covalently linked to the metal complexing group. Many examples of specific modifications of the BBN(8-14) that can be made to produce sequences with high antagonistic and agonistic binding affinity for GRP receptors have been reported by numerous investigations [Davis et al., 1992; Hoffken, 1994; Moody et al., 1996; Coy et al., 1988; Cai et al., 1994; Moody et al., 1995; Leban et al., 1994; Cai et al., 1992].

In a preferred embodiment of the present invention, the metal complexing group or moiety is a chelating agent or chelator which complexes to metals such as $^{105}\text{Rh-}$, $^{186/188}\text{Re-}$, $^{99\text{m}}\text{Tc}$, ^{153}Sm , ^{166}Ho , ^{90}Y or ^{199}Au . The chelating agent or chelator is attached or bound to the GRP agonist "binding region" to produce a conjugate that retains its capability for high affinity and specific binding to GRP receptors.

In a more preferred embodiment of the present invention, the GRP agonist is a bombesin (BBN) analogue and/or a derivative thereof. The BBN derivative or analog thereof preferably contains either the same primary structure of the BBN binding region [i.e., BBN(8-14)]

or similar primary structures, with specific amino acid substitutions, that will specifically bind to GRP receptors with better or similar binding affinities as BBN alone (i.e., $K_d \cong 1-5$ nmolar). Compounds containing this BBN binding region (or binding moiety), when covalently linked to
5 other groups (e.g., a radiometal chelate), are also referred to as BBN conjugates.

In general, the compounds of the present invention have a structure of the general formula:

10 X-Y-B

wherein X is a group capable of complexing a metal, such as a radiometal; Y is a covalent bond on a spacer group; and B is a bombesin agonist binding moiety.

15 The metal bound to the metal complexing group can be any suitable metal chosen for a specific therapeutic or diagnostic use including transition metals and γ and β emitting isotopes. Preferably, the metal is a radiometal such as ^{105}Rh -, $^{99\text{m}}\text{Tc}$ -, $^{186/188}\text{Re}$ -, ^{153}Sm -, ^{166}Ho -, ^{90}Y -, and ^{199}Au - whose chelates can be covalently linked (i.e., conjugated) to the specific
20 BBN binding region via the N-terminal end of the primary binding sequence (e.g., BBN-8 or Trp^8) as shown in Figure 1.

In a preferred embodiment, the radiometal complexes are positioned by being spaced apart from or remotely from the amino acid Trp⁸ by the spacer groups. The spacer groups can include a peptide (i.e., \geq 1 amino acid in length), a hydrocarbon spacer of C₁-C₁₀ or a combination of thereof. Preferably, the hydrocarbon spacer has is a C₃-C₉ group. The resulting radio-labeled BBN conjugates retain high binding affinity and specificity for GRP receptors and are subsequently internalized inside of the cell.

10 The BBN conjugates can further incorporate a spacer group or component to couple the binding moiety to the metal chelator (or metal binding backbone) while not adversely affecting either the targeting function of the BBN-binding moiety or the metal complexing function of the metal chelating agent.

15

 The term "spacer group" or "linker" refers to a chemical group that serves to couple the BBN binding moiety to the metal chelator while not adversely affecting either the targeting function of the BBN binding moiety or the metal complexing function of the metal chelator.

20 Suitable spacer groups include peptides (i.e., amino acids linked together) alone, a non-peptide group (e.g., hydrocarbon chain) or a combination of an amino acid sequence and a non-peptide spacer. The type of spacer

group used in most of the experimental studies described below in the Examples section were composed of a combination of L-glutamine and hydrocarbon spacers. A pure peptide spacer could consist of a series of amino acids (e.g., diglycine, triglycine, gly-gly-glu, etc.), in which the
5 total number of atoms between the N-terminal residue of the BBN binding moiety and the metal chelator in the polymeric chain is ≤ 12 atoms.

The spacer can also include a hydrocarbon chain [i.e., $R_1-(CH_2)_n-R_2$] wherein n is 0-10, preferably $n = 3$ to 9, R_1 is a group (e.g.,
10 H_2N- , $HS-$, $-COOH$) that can be used as a site for covalently linking the ligand backbone or the preformed metal chelator or metal complexing backbone; and R_2 is a group that is used for covalent coupling to the N-terminal NH_2 -group of the BBN binding moiety (e.g., R_2 is an activated $COOH$ group). Several chemical methods for conjugating ligands (i.e.,
15 chelators) or preferred metal chelates to biomolecules have been well described in the literature [Wilbur, 1992; Parker, 1990; Hermanson, 1996; Frizberg et al., 1995]. One or more of these methods could be used to link either the uncomplexed ligand (chelator) or the radiometal chelate to the spacer group or to link the spacer group to the BBN(8-14) derivatives.
20 These methods include the formation of acid anhydrides, aldehydes, arylisothiocyanates, activated esters, or N-hydroxysuccinimides [Wilbur, 1992; Parker, 1990; Hermanson, 1996; Frizberg et al., 1995].

The term "metal complexing chelator" refers to a molecule that forms a complex with a metal atom that is stable under physiological conditions. That is, the metal will remain complexed to the chelator backbone *in vivo*. More particularly, a metal complexing chelator is a molecule that complexes to a radionuclide metal to form a metal complex that is stable under physiological conditions and which also has at least one reactive functional group for conjugation with the BBN agonist binding moiety. Metal complexing chelators can include monodentate and polydentate chelators [Parker, 1990; Frizberg et al., 1995; Lister-James et al., 1997; Li et al., 1996b; Albert et al., 1991; Pollak et al., 1996; de Jong et al., 1997; Smith et al., 1997]. Metal complexing chelators include tetradentate metal chelators which can be macrocyclic and have a combination of four nitrogen and/or sulphur metal-coordinating atoms [Parker et al., 1990; Li et al., 1996b] and are designated as N₄, S₄, N₃S, N₂S₂, NS₃, etc. as shown in Figure 2. A number of suitable multidentate chelators that have been used to conjugate proteins and receptor-avid molecules have been reported [Frizberg et al., 1995; Lister-James et al., 1997; Li et al., 1996b; Albert et al., 1991; Pollak et al., 1996; de Jong et al., 1997]. These multidentate chelators can also incorporate other metal-coordinating atoms such as oxygen and phosphorous in various combinations. The metal binding complexing moiety can also include "3+1" chelators [Seifert et al., 1998].

For diagnostic purposes, metal complexing chelators preferably include chelator backbones for complexing the radionuclide metal ^{99m}Tc . For therapeutic purposes, metal complexing chelators preferably include chelator backbones that complex the radionuclide metals ^{105}Rh , $^{186/188}\text{Re}$, ^{153}Sm , ^{90}Y , ^{166}Ho , and ^{199}Au [Schubiger et al., 1996; Hoffken, 1994].

As was briefly described above, the term "bombesin agonist" or "BBN agonist" refers to compounds that bind with high specificity and affinity to GRP receptors, and upon binding to the GRP receptor, are intracellularly internalized. Suitable compounds include peptides, peptidomimetics and analogues and derivatives thereof. In particular, previous work has demonstrated that the region on the BBN peptide structure required for binding to GRP receptors spans from residue 8 through 14 [Davis et al., 1992; Hoffken, 1994; Moody et al., 1996; Coy, 1988; Cai et al., 1994]. The presence of methionine (Met) at position BBN-14 will generally confer agonistic properties while the absence of this residue at BBN-14 generally confers antagonistic properties [Hoffken, 1994].

It is well documented in the art that there are a few and selective number of specific amino acid substitutions in the BBN (8-14)

binding region (e.g., D-Ala¹¹ for L-Gly¹¹ or D-Trp⁸ for L-Trp⁸), which can be made without decreasing binding affinity [Leban et al., 1994; Qin et al., 1994; Jensen et al., 1993]. In addition, attachment of some amino acid chains or other groups to the N-terminal amine group at position BBN-8
5 (i.e., the Trp⁸ residue) can dramatically decrease the binding affinity of BBN analogues to GRP receptors [Davis et al., 1992; Hoffken, 1994; Moody et al., 1996; Coy, et al., 1988; Cai et al., 1994]. In a few cases, it is possible to append additional amino acids or chemical moieties without decreasing binding affinity. The effects of conjugating various side
10 chains to BBN-8 on binding affinity, therefore, is not predictable.

The BBN conjugates of the present invention can be prepared by various methods depending upon the selected chelator. The peptide portion of the conjugate can be most conveniently prepared by
15 techniques generally established and known in the art of peptide synthesis, such as the solid-phase peptide synthesis (SPPS) approach. Solid-phase peptide synthesis (SPPS) involves the stepwise addition of amino acid residues to a growing peptide chain that is linked to an insoluble support or matrix, such as polystyrene. The C-terminal residue of the peptide is
20 first anchored to a commercially available support with its amino group protected with an N-protecting agent such as a t-butyloxycarbonyl group (tBoc) or a fluorenylmethoxycarbonyl (Fmoc) group. The amino

protecting group is removed with suitable deprotecting agents such as TFA in the case of tBOC or piperidine for FMOC and the next amino acid residue (in N-protected form) is added with a coupling agent such as dicyclocarbodiimide (DCC). Upon formation of a peptide bond, the
5 reagents are washed from the support. After addition of the final residue, the peptide is cleaved from the support with a suitable reagent such as trifluoroacetic acid (TFA) or hydrogen fluoride (HF).

The spacer groups and chelator components are then
10 coupled to form a conjugate by reacting the free amino group of the Trp⁸ residue of the BBN binding moiety with an appropriate functional group of the chelator, metal chelator or spacer group, such as a carboxyl group or activated ester.

15 The BBN conjugate can also incorporate a metal complexing chelator backbone that is peptidic and compatible with solid-phase peptide synthesis. In this case, the chelator backbone can be added to the BBN binding moiety in the same manner as described above or, more conveniently, the metal complexing chelator backbone coupled to
20 the BBN binding moiety can be synthesized *in toto* starting from the C-terminal residue of the peptide and ending with the N-terminal residue of the metal complexing chelator structure.

The chelator backbones used in accordance with the present invention are commercially available or they could be made by methods similar to those outlined in the literature [Frizberg et al., 1995; Lister-James et al., 1997; Li et al., 1996b; Albert et al., 1991; Pollak et al., 1996; de Jong et al., 1997; Smith et al., 1997; Seifert et al., 1998].

Attachment of the spacer groups to functionalizable atoms appended to the ligand backbone can be performed by standard methods known to those skilled in the art. For example, the HOBt/HBTU activated -COOH group on 5-aminovaleric acid (5-AVA) was reacted with the N-terminal amine on Gln⁷ to produce an amide linkage as shown in Figure 3.

Similarly, the -COOH group attached to the characterized [16]aneS₄ ligand was conjugated to the amine group on the hydrocarbon spacer (shown below) by reaction of the HOBt/HBTU activated carboxyl group appended to the [16]aneS₄ macrocycle with the terminal amine group on 5-AVA to form BBN-37 as shown in Figure 4. Other standard conjugation reactors that produce covalent linkages with amine groups can also be used [Wilbur, 1992; Parker, 1990].

The chelating framework, conjugated via Trp⁸, complexes the radiometals should form a 1:1 chelator to metal ratio. Since ^{99m}Tc has a short half-life (6 hour) and is a diagnostic radionuclide, the method of forming the ^{99m}Tc-BBN analogues should permit complexation (either

directly or by transmetallation) of ^{99m}Tc to the conjugated chelating framework in a one-step, high yield reaction (exemplified below in the Experimental Section).

5 In contrast, the longer half lives of the therapeutic radionuclides (e.g., ^{105}Rh , $^{186/188}\text{Re}$, ^{153}Sm , ^{166}Ho , ^{90}Y , or ^{199}Au) permit formation of the corresponding radiolabeled BBN analogues by either a one step high yield complexation step or by preforming a ^{105}Rh -, $^{186/188}\text{Re}$ -, ^{153}Sm , ^{166}Ho , ^{90}Y or ^{199}Au chelate synthon followed by conjugation of the
10 preformed complex to the N-terminal end of the BBN binding moiety. In all cases, the resulting specific activity of the final radiolabeled BBN derivative must be high (i.e., $> 1\text{Ci}/\mu\text{mole}$).

Re- and Tc-conjugates

15 Re and Tc are both in row VIIB of the Periodic Table and they are chemical congeners. Thus, for the most part, the complexation chemistry of these two metals with ligand frameworks that exhibit high *in vitro* and *in vivo* stabilities are the same [Eckelman, 1995]. Many ^{99m}Tc or
20 $^{186/188}\text{Re}$ complexes, which are employed to form stable radiometal complexes with peptides and proteins, chelate these metals in their +5 oxidation state [Lister-James et al., 1997]. This oxidation state makes it

possible to selectively place ^{99m}Tc - or $^{186/188}\text{Re}$ into ligand frameworks already conjugated to the biomolecule, constructed from a variety of $^{99m}\text{Tc(V)}$ and/or $^{186/188}\text{Re(V)}$ weak chelates (e.g., ^{99m}Tc - glucoheptonate, citrate, gluconate, etc.) [Eckelman, 1995; Lister-James et al., 1997; Pollak et al., 1996]. Tetradentate ligand frameworks have been shown to form well-defined, single chemical species in high specific activities when at least one thiol group or at least one hydroxymethylene phosphine group is present on the ligand backbone [Smith et al., 1997].

10 Ligands which form stable Tc(V) or Re(V) tetradentate complexes containing, but not limited to, amino N-atoms, amido-N-atoms, carboxy-O-atoms and thioether-S-atoms, are donor atoms that can also be present [Eckelman, 1995; Fritzberg et al., 1992; Parker, 1990; Frizberg et al., 1995; Pollak et al., 1996; Seifert et al., 1998]. Depending upon the mix of donor atoms (groups), the overall complex charge normally ranges from -1 to +1.

Incorporation of the metal within the conjugate can be achieved by various methods commonly known in the art of coordination chemistry. When the metal is technetium-99m, the following general procedure can be used to form a technetium complex. A peptide-chelator conjugate solution is formed by initially dissolving the conjugate in

aqueous alcohol such as ethanol. The solution is then degassed to remove oxygen. When an -SH group is present in the peptide, the thiol protecting group are removed with a suitable reagent, for example with sodium hydroxide, and are then neutralized with an organic acid such as acetic acid (pH 6.0-6.5). In the labeling step, sodium pertechnetate obtained from a molybdenum generator is added to a solution of the conjugate with a sufficient amount of a reducing agent, such as stannous chloride, to reduce technetium and is then heated. The labeled conjugate can be separated from the contaminants $^{99m}\text{TcO}_4^-$ and colloidal $^{99m}\text{TcO}_2$ chromatographically, for example with a C-18 Sep Pak cartridge [Millipore Corporation, Waters Chromatography Division, 34 Maple Street, Milford, Massachusetts 01757].

In an alternative method, the labeling can be accomplished by a transchelation reaction. The technetium source is a solution of technetium complexed with labile ligands facilitating ligand exchange with the selected chelator. Examples of suitable ligands for transchelation includes tartrate, citrate, gluconate, and heptagluconate. It will be appreciated that the conjugate can be labeled using the techniques described above, or alternatively, the chelator itself may be labeled and subsequently coupled to the peptide to form the conjugate; a process referred to as the "prelabeled chelate" method.

When labeled with diagnostically and/or therapeutically useful metals, peptide-chelator conjugates or pharmaceutically acceptable salts, esters, amides, and prodrugs of the present invention can be used to treat and/or detect cancers, including tumors, by procedures established in the art of radiodiagnostics and radiotherapeutics. [Bushbaum, 1995; Fischman et al., 1993; Schubiger et al., 1996; Lowbertz et al., 1994; Krenning et al., 1994]. A conjugate labeled with a radionuclide metal, such as technetium-99m, can be administered to a mammal, including human patients or subjects, by intravenous or intraperitoneal injection in a pharmaceutically acceptable carrier and/or solution such as salt solutions like isotonic saline. The amount of labeled conjugate appropriate for administration is dependent upon the distribution profile of the chosen conjugate in the sense that a rapidly cleared conjugate may be administered in higher doses than one that clears less rapidly. Unit doses acceptable for Tc-99m imaging radiopharmaceuticals inflammation are in the range of about 5-40 mCi for a 70kg individual. *In vivo* distribution and localization can be tracked by standard scintigraphic techniques at an appropriate time subsequent to administration; typically between thirty minutes and 180 minutes depending upon the rate of accumulation at the target site with respect to the rate of clearance at non-target tissue.

The compounds of the present invention can be administered to a patient alone or as part of a composition that contains other components such as excipients, diluents, and carriers, all of which are well-known in the art. The compounds can be administered to patients
5 either intravenously or intraperitoneally.

There are numerous advantages associated with the present invention. The compounds made in accordance with the present invention forms a stable, well-defined ^{99m}Tc or $^{186/188}\text{Re}$ conjugate analogues of BBN
10 agonists. Similar BBN against analogues can also be made by using appropriate chelator frameworks for the respective radiometals, to form stable-well-defined products labeled with ^{153}Sm , ^{90}Y , ^{166}Ho , ^{105}Rh or ^{199}Au . The radiolabeled BBN agonist conjugates selectively bind to neoplastic cells expressing GRP receptors become internalized and are retained in
15 the tumor cells for extended time periods. Incorporating the spacer group between the metal chelator and the BBN agonist binding moiety maximizes the uptake and retention of the radioactive metal inside of the neoplasts or cancer cells. The radioactive material that does not reach (i.e., does not bind) the cancer cells is preferentially excreted efficiently
20 into the urine with minimal radiometal retention in the kidneys.

The following examples are presented to illustrate specific

embodiments and demonstrate the utility of the present invention.

Experimental Section

5 Example I: Synthesis and *in vitro* binding assessment of synthetic
 BBN analogues employing hydrocarbon chain spacers

A. Synthesis:

10 Many BBN analogues were synthesized by Solid Phase
 Peptide Synthesis (SPPS). Each peptide was prepared by SPPS using an
 Applied Biosystems Model 432A peptide synthesizer. After cleavage of
 each BBN analogue from the resin using Trifluoroacetic acid (TFA), the
 peptides were purified by C₁₈ reversed-phase HPLC using a Vydac HS54
15 column and CH₃CN/H₂O containing 0.1% TFA as the mobile phase. After
 collection of the fraction containing the desired BBN peptide (approx. 80-
 90% yield in most cases), the solvent was evaporated. The identity of
 each BBN peptide was confirmed by FAB-mass spectrometry,
 Department of Chemistry - Washington University, St. Louis, MO.

20

 Various amino acid sequences (in some cases including
 different chemical moieties) were conjugated to the N-terminal end of the
 BBN binding region (i.e., to BBN-8 or Trp⁸). BBN analogue numbers

9,15,15i, 16, 16i and 18 were synthesized as examples of N-terminal modified peptides as shown in Figure 5.

Various tethered N-terminal (via Trp⁸) BBN analogues

5 were also synthesized by SPPS as exemplified by BBN-40, BBN-41, BBN-42, BBN-43, BBN-44, BBN-45, and BBN-49 as shown in Figure 6. In these particular tethered peptides, a Glu residue was attached to Trp⁸ followed by attachment of Fmoc protected terminal amine groups separated from a -COOH group by 3-, 4-, 5-, 6-, 8- and 11-carbon chain
10 (CH) spacers (Figure 6). These Fmoc protected acids were added as the terminal step during the SPPS cycle. As described previously, each of the BBN analogues was purified by reversed-phase HPLC and characterized by high resolution Mass Spectroscopy. Peptide 49 employed only glutamine as the spacer group.

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The [16]aneS₄ macrocyclic ligand was conjugated to selected tethered BBN analogues shown in Figure 6. The -OCH₂COOH group on the [16]aneS₄ macrocycle derivative was activated via HOBt/HBTU so that it efficiently formed an amide bond with the terminal
20 NH₂ group on the spacer side arm (following deprotection). The corresponding [16]aneS₄ tethered BBN derivatives were produced and examples of 4 of these derivatives (i.e., BBN-22, -37, -46 and -47) are

shown in Figure 7. As previously described, each [16]aneS₄ BBN derivative was purified by reversed phase HPLC and characterized by FAB Mass Spectroscopy.

5 B. *In Vitro* Binding Affinities

The binding affinities of the synthetic BBN derivatives were assessed for GRP receptors on Swiss 3T3 cells and, in some cases, on a variety of human cancer cell lines, that express GRP receptors. The IC₅₀'s of each derivative was determined relative to (i.e., in competition with) ¹²⁵I-Tyr⁴-BBN (the K_d for ¹²⁵I-Tyr⁴-BBN for GRP receptors in Swiss 3T3 cells is reported to be 1.6±0.4 nM) [Zueht et al., 1991]. The cell binding assay methods used to measure the IC₅₀'s is standard and was used by techniques previously reported [Jensen et al., 1993; Cai et al., 1994; Cai et al., 1992]. The methods used for determining IC₅₀'s with all GRP receptor binding of GRP receptors on all cell lines was similar. The specific method used to measure IC₅₀'s on Swiss 3T3 cells is briefly described as follows:

20 Swiss 3T3 mouse fibroblasts are grown to confluence in 48 well microtiter plates. An incubation media was prepared consisting of HEPES (11.916g/l), NaCl (7.598 g/l), KCl (0.574 g/l), MgCl₂ (1.106 g/l),

EGTA (0.380 g/l), BSA (5.0 g/l), chymostatin (0.002 g/l), soybean trypsin inhibitor (0.200 g/l), and bacitracin (0.050 g/l). The growth media was removed, the cells were washed twice with incubation media, and incubation media was returned to the cells. ^{125}I -Tyr⁴-BBN (0.01 uCi) was added to each well in the presence of increasing concentrations of the appropriate competitive peptide. Typical concentrations of displacing peptide ranged from 10^{-12} to 10^{-5} moles of displacing ligand per well. The cells were incubated at 37°C for forty minutes in a 95%O₂/5%CO₂ humidified environment. At forty minutes post initiation of the incubation, the medium was discarded, and the cells were washed twice with cold incubation media. The cells were harvested from the wells following incubation in a trypsin/EDTA solution for five minutes at 37°C. Subsequently, the radioactivity, per well, was determined and the maximum % total uptake of the radiolabeled peptide was determined and normalized to 100%.

C. Results of Binding Affinity Measurements

The IC₅₀ values measured for the BBN derivatives synthesized in accordance with this invention showed that appending a peptide side chain and other moieties via the N-terminal BBN-8 residue (i.e., Trp⁸) produced widely varying IC₅₀ values. For example, see IC₅₀ values shown for BBN 11, 15i, 16i, and 18 in Figures 5 and 8. The

observations are consistent with previous reports showing highly variable IC_{50} values when derivatizing BBN(8-13) or BBN(8-14) with a predominantly short chain of amino acid residues [Hoffken, 1994]. In contrast, when a hydrocarbon spacer of 3- to 11-carbons was appended between BBN(7-14) and the [16]aneS₄ macrocycle, the IC_{50} 's were found to be surprisingly relatively constant and in the 1-5 nM range (i.e., see IC_{50} values for BBN-22, -37, -46 and -47 as shown in Figure 7). These data suggest that using relatively simple spacer groups to extend ligands some distance from the BBN binding region [e.g., BBN(8-14)] can produce derivatives that maintain binding affinities in the 1-5 nmolar range.

D. Cell Binding Studies

Results illustrated in Figure 9 show that when the RhCl₂-[16]aneS₄ complex separated from Trp⁸ by only a glutamine (Glu⁷), the IC_{50} of this conjugate (i.e., Rh-BBN-22) was 37.5 nM. However, when a five (5) carbon spacer or an eight (8) carbon spacer was present (i.e., Rh-BBN-37 and Rh-BBN-47), the IC_{50} 's remained below 5 nM as shown in Figure 9. These data demonstrate that a straight chain spacer (along with glu⁷) to move the +1 charged Rh-S₄-chelate away from the BBN binding region will result in a metallated BBN analogue with sufficiently high binding affinities to GRP receptors for *in vivo* tumor targeting

applications.

E. ^{105}Rh Radiolabeled BBN Analogues

The ^{105}Rh conjugates of BBN-22, BBN-37, BBN-46 and
5 BBN-47 were synthesized using a ^{105}Rh -chloride reagent from the
Missouri University Research Reactor (MURR). This reagent was
obtained as ^{105}Rh -chloride, a no-carrier-added (NCA) product, in 0.1-1M
HCl. The pH of this reagent was adjusted to 4-5 using 0.1-1.0 M NaOH
dropwise and it was added to approximately 0.1 mg of the $^{16}\text{S}_4$ -
10 conjugated BBN derivatives in 0.9% aqueous NaCl and 10% ethanol.
After the sample was heated at 80°C for one hour, the ^{105}Rh -BBN
analogues were purified using HPLC. In each case, a NCA or high
specific activity product was obtained since the non-metallated S_4 -BBN
conjugates eluted at a retention time well after the ^{105}Rh -BBN conjugates
15 eluted. For example, the retention time of ^{105}Rh -BBN-37 was 7.1 min
while BBN-37 eluted at 10.5 min from a C-18-reversed phase column
eluted with $\text{CH}_3\text{CN}/\text{H}_2\text{O}$ containing 0.1% TFA as shown in Figure 10A-B.

Example II: Retention of ^{105}Rh -BBN Analogues in Cancer Cells

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Once the radiometal has been specifically "delivered" to
cancer cells (e.g., employing the BBN binding moiety that specifically

targets GRP receptors on the cell surface), it is necessary that a large percentage of the "delivered" radioactive atoms remain associated with the cells for a period time of hours or longer to make an effective radiopharmaceutical for effectively treating cancer. One way to achieve this association is to internalize the radiolabeled BBN conjugates within the cancer cell after binding to cell surface GRP receptors.

In the past, all of the work with synthetic-BBN analogues for treatment of cancers focused on synthesizing and evaluating antagonists [Davis et al., 1992; Hoffken, 1994; Moody et al., 1996; Coy et al., 1988; Cai et al., 1994; Moody et al., 1995; Leban et al., 1994; Cai et al., 1992]. After evaluating synthetic BBN analogues that would be predicted to be either agonists or antagonists, applicants found that derivatives of BBN(8-14) (i.e., those with the methionine or amidated methionine at BBN-14) are rapidly internalized (i.e., in less than two minutes) after binding to the cell surface GRP receptors. Several radiolabeled BBN(8-14) analogues that were studied to determine their internalization and intracellular trapping efficiencies were radioiodinated (i.e., ^{125}I) derivatives. The results of these studies demonstrated that despite rapid internalization after ^{125}I -labeled BBN analogue binding to GRP receptors in Swiss 3T3 cells, the ^{125}I was rapidly expelled from the cells [Hoffman et al., 1997] as shown in Figure 11. Thus, these ^{125}I -BBN

derivatives were not suitable for further development.

In contrast, the ^{105}Rh -BBN(8-14) derivatives that bind to GRP receptors are not only rapidly internalized, but there is a large percentage of the ^{105}Rh activity that remains trapped within the cells for 5 hours (and in some cell lines > twenty four hours). This observation indicates that these radiometallated BBN derivatives have real utility as radiopharmaceuticals for *in vivo* targeting of neoplasms expressing GRP receptors.

10 Experiments designed to determine the fraction of a radiotracer internalized within cells were performed by adding excess ^{125}I - or ^{105}Rh -BBN derivatives to the cell incubation medium. After establishment of equilibrium after a forty minute incubation, the media surrounding the cells was removed and the cells were washed with fresh 15 media containing no radioactivity. After washing, the quantity of radioactivity associated with the cells was determined (i.e., total counts per min (TCPM) of ^{125}I or ^{105}Rh associated with the cells). The cells were then incubated in a 0.2M acetic acid solution (pH 2.5) which caused the surface proteins (incl., GRP receptors) to denature and release all surface 20 bound radioactive materials. After removing this buffer and washing, the cells were counted again. The counts per minute (c.p.m.) associated with the cells at that point were only related to the ^{125}I or ^{105}Rh that remained

trapped inside of the cells.

To determine intracellular retention, a similar method was employed. However, after washing the cells with fresh (non-radioactive) incubation media, the cells were incubated in the fresh media at different time periods after washing away all extracellular ^{125}I - or ^{105}Rh -BBN analogues. After each time period, the methods used to determine TOTAL c.p.m. and intracellular c.p.m. after washing with a 0.2M acetic acid solution at pH 2.5 were the same as described above and the percent ^{125}I or ^{105}Rh remaining trapped inside of the cells was calculated. Figure 12 is a graph of results of efflux experiments using Swiss 3T3 cells with ^{125}I -Lys³-BBN. The results show that there is rapid efflux of the ^{125}I from inside of these cells with less than 50% retained at fifteen minutes and by sixty minutes, less than 20% remained as shown in Figure 12.

In contrast, studies with all of the ^{105}Rh -[16]aneS₄-BBN agonist derivatives that are internalized inside of the cells showed substantial intracellular retention of ^{105}Rh by the GRP receptor expressing cells. For example, results of studies using ^{105}Rh -BBN-37 (see Figure 9) in conjunction with Swiss 3T3 cells showed that approximately 50% of the ^{105}Rh activity remains associated with the cells at sixty minutes post-washing and approximately 30% of ^{105}Rh remained inside of the cells after four hours as shown in Figure 13. Note that at least 5% of the ^{105}Rh is

surface bound at \geq sixty minutes.

The ^{105}Rh -BBN derivatives shown in Figure 9 all have an amidated methionine at position BBN-14 and are expected to be agonists [Jensen et al., 1993]. Therefore, they would be predicted to rapidly

5 internalize after binding to GRP receptors on the cell surface [Reile et al., 1994; Bjisterbosch et al., 1995; Smythe et al., 1991], which was confirmed by applicants' data. Referring to Figure 14, ^{105}Rh -BBN-61, a BBN analogue with no amino acid at position BBN-14 (i.e., a ^{105}Rh -BBN(8-13) derivative), was synthesized and studied. This BBN analogue
10 has a high bonding affinity (i.e., $\text{IC}_{50} = 30 \text{ nM}$). This type of derivative is expected to be an antagonist and as such will not internalize [Jensen et al., 1993; Smythe et al., 1991]. Results of efflux studies with ^{105}Rh -BBN-61 using Swiss 3T3 cells showed that immediately following washing with fresh incubation buffer (i.e., $t=0$), essentially all of the ^{105}Rh associated
15 with these cells is on the cell surface, as expected. Furthermore, after only one hour of incubation, less than 10% remained associated with these cells in any fashion (see Figures 15 and 16). These data indicate that ^{105}Rh -antagonists with structures similar to the ^{105}Rh -BBN agonists (i.e., those shown in Figure 9) are not good candidates for development of
20 radiopharmaceuticals since they are neither trapped in nor on the GRP receptor expressing cells to nearly the same extent as the radiometallated BBN agonists.

EXAMPLE III: Human Cancer Cell Line Studies

5 *In vitro* cell binding studies of ^{105}Rh -BBN-37 with two different human cancer cell lines that express GRP receptors (i.e., the PC-3 and CF-PAC1 cell lines), which are tumor cells derived from patients with prostate CA and pancreatic CA, as shown in Figures 17A-B and 18A-B, respectively) were performed. Results of these studies

10 demonstrated consistency with ^{105}Rh -BBN-37 binding and retention studies using Swiss 3T3 cells. Specifically, the binding affinity of Rh-BBN-37 was high (i.e., $\text{IC}_{50} \cong 7 \text{ nM}$) with both human cancer cell lines as shown in Table 1. In addition, in all cells, the majority of the ^{105}Rh -BBN-37 was internalized and perhaps a major unexpected result was that the

15 retention of the ^{105}Rh -tracer inside of the cells was significantly better than retention in Swiss 3T3 cells as shown in Figures 17 and 18. For example, it is particularly remarkable that the percentage of ^{105}Rh -BBN-37 that remained associated with both the CFPAC-1 and PC-3 cell line was >80% at two hours after removing the extracellular activity by washing with

20 fresh incubation buffer (see Figures 17 and 18).

EXAMPLE IV: *IN VIVO* STUDIES

5 Biodistribution studies were performed by intravenous
(I.V.) injection of either ^{105}Rh -BBN-22 or ^{105}Rh -BBN-37 into normal
mice. In these studies, unanesthetized CF-1 mice (15-22g, body wt.) were
injected I.V. via the tail vein with between one (1) to five (5) uCi (37-185
KBq) of the ^{105}Rh - labeled agent. Organs, body fluids and tissues were
10 excised from animals sacrificed at 30, 60 and 120 minutes post-injection
(PI). The tissues were weighed, washed in saline (when appropriate) and
counted in a NaI well counter. These data were then used to determine
the percent injected dose (% ID) in an organ or fluid and the %ID per
gram. The whole blood volume of each animal was estimated to be 6.5
15 percent of the body weight. Results of these studies are summarized in
Tables 2 and 3.

Results from these studies showed that both the ^{105}Rh -
BBN-22 and ^{105}Rh -BBN-37 were cleared from the blood stream,
20 predominantly via the kidney into the urine. Specifically, $68.4 \pm 6.6\%$
and $62.3 \pm 5.8\%$ of the ID was found in urine at two hours PI of ^{105}Rh -
BBN-22 and ^{105}Rh -BBN-37, respectively (see Tables 2 and 3). An

unexpected finding was that the % ID of ^{105}Rh that remained deposited in the kidneys of these animals was only 2.4 ± 0.6 % ID and 4.6 ± 1.3 % ID at two hours PI of ^{105}Rh -BBN-22 and ^{105}Rh -BBN-37 (see Tables 2 and 3). This is much less than would be expected from previously reported data where radiometallated peptides and small proteins have exhibited renal retention of the radiometal that is $> 10\%$ ID and usually much $> 10\%$ [Duncan et al., 1997]. The reason for reduced renal retention of ^{105}Rh -BBN analogues is not known, however, this result demonstrates a substantial improvement over existing radiometallated peptides.

10

Biodistribution studies also demonstrated another important *in vivo* property of these radiometallated BBN analogues. Both ^{105}Rh -BBN-22 and ^{105}Rh -BBN-37 are efficiently cleared from organs and tissues that do not express GRP receptors (or those that do not have their GRP-receptors accessible to circulating blood). The biodistribution studies in mice demonstrated specific uptake of ^{105}Rh -BBN-22 and ^{105}Rh -BBN-37 in the pancreas while other non-excretory organs or tissues (i.e., heart, brain, lung, muscle, spleen) exhibited no uptake or retention (Tables 2 and 3). Both ^{105}Rh -BBN-22 and ^{105}Rh -BBN-37 were removed from the blood stream by both the liver and kidneys with a large fraction of the ^{105}Rh removed by these routes being excreted into the intestines and the bladder, respectively. It is important to note that the % ID/gm in the

15
20

pancreas of ^{105}Rh -BBN-22 and ^{105}Rh -BBN-37 was $3.9 \pm 1.3\%$ and $9.9 \pm 5.4\%$, respectively at 2 hr, PI. Thus, the ratios of % ID/gm of ^{105}Rh -BBN-22 in the pancreas relative to muscle and blood were 16.2 and 7.6, respectively. The ratios of % ID/gm of ^{105}Rh -BBN-37 in the pancreas relative to muscle and blood were 25.4 and 29.1, respectively. These data demonstrated selective *in vivo* targeting of these radiometallated BBN analogues to cells expressing GRP receptors [Zhu et al., 1991; Qin et al., 1994] and efficient clearance from non-target tissues. If cancer cells that express GRP receptors are present in the body, these results indicate radiometallated BBN analogues will be able to target them with a selectivity similar to the pancreatic cells.

A comparison of the pancreatic uptake and retention of ^{105}Rh -BBN-22 with ^{105}Rh -BBN-37 demonstrated that ^{105}Rh -BBN-37 deposits in the pancreas with a 2-fold better efficiency than ^{105}Rh -BBN-22 (i.e., $3.6 \pm 1.2\%$ ID and $2.3 \pm 1.0\%$ ID) for ^{105}Rh -BBN-37 at one and two hours PI, respectively, vs. $1.2 \pm 0.5\%$ ID and $1.0 \pm 0.1\%$ ID for ^{105}Rh -BBN-22 at one and two hours PI). This data is consistent with the >2-fold higher uptake and retention of ^{105}Rh -BBN-37 found in the *in vitro* studies shown in Figure 16.

Example V: Synthesis and *in vitro* binding measurement of synthetic
BBN conjugate analogues employing amino acid chain
spacers

5 A. Synthesis

Five BBN analogues were synthesized by SPPS in which between
2 to 6 amino acid spacer groups were inserted to separate a S₄-macrocyclic
chelator from the N-terminal trp⁸ on BBN(8-14) (Figure 19). Each
10 peptide was prepared by SPPS using an Applied Biosystems Model 432A
peptide synthesizer. After cleavage of each BBN analogue from the resin
using Trifluoroacetic acid (TFA), the peptides were purified by C₁₈
reversed-phase HPLC using a Vydac HS54 column and CH₃CN/H₂O
containing 0.1% TFA as the mobile phase. After collection of the fraction
15 containing the desired BBN peptide, the solvent was evaporated. The
identity of each BBN peptide was confirmed by FAB-mass spectrometry
(Department of Chemistry - Washington University, St. Louis, MO).

Various amino acid sequences (in some cases containing
20 different R group moieties) were conjugated to the N-terminal end of the
BBN binding region (i.e., to BBN-8 or Trp⁸). BBN analogue numbers 96,
97, 98, 99 and 101 were synthesized as examples of N-terminal modified
peptides in which the [16]aneS₄ macrocycle BFCA was separated from

trp⁸ on BBN(8-14) by various amino acid sequences as shown in Figure 19.

The [16]aneS₄ macrocyclic ligand was conjugated to
5 selected tethered BBN analogues. The -OCH₂COOH group on the [16]aneS₄ macrocycle derivative was activated via HOBt/HBTU so that it efficiently formed an amide bond with the terminal NH₂ group on the spacer side arm (following deprotection). The corresponding [16]aneS₄ tethered BBN derivatives were produced and examples of 5 of these
10 derivatives (i.e., BBN-96, 97, 98, 99 and 101) are shown in Figure 19. As previously described, each [16]aneS₄ BBN derivative was purified by reversed phase HPLC and characterized by FAB Mass Spectroscopy.

B. *In Vitro* Binding Affinities

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The binding affinities of the synthetic BBN derivatives were assessed for GRP receptors on Swiss 3T3 cells, PC-3 cells and CF PAC-1 cells. The IC₅₀'s of each of derivative was determined relative to (i.e., in competition with) ¹²⁵I-Tyr⁴-BBN. The cell binding assay methods
20 used to measure the IC₅₀'s is standard and was used by techniques previously reported [Jensen et al., 1993; Cai et al., 1992; Cai et al., 1994]. The methods used for determining IC₅₀'s with all BBN analogue binding

to GRP receptors present on all three cell lines was similar. The specific method used to measure IC_{50} 's on Swiss 3T3 cells is briefly described as follows:

- 5 Swiss 3T3 mouse fibroblasts are grown to confluence in 48 well microliter plates. An incubation media was prepared consisting of HEPES (11.916g/l), NaCl (7.598 g/l), KCl (0.574 g/l), $MgCl_2$ (1.106 g/l), EGTA (0.380 g/l), BSA (5.0 g/l), chymostatin (0.002 g/l), soybean trypsin inhibitor (0.200 g/l), and bacitracin (0.050 g/l). The growth
- 10 media was removed, the cells were washed twice with incubation media, and incubation media was returned to the cells. ^{125}I -Tyr⁴-BBN (0.01 μ Ci) was added to each well in the presence of increasing concentrations of the appropriate competitive peptide. Typical concentrations of displacing peptide ranged from 10^{-12} to 10^{-5} moles of displacing ligand per well. The
- 15 cells were incubated at 37°C for forty minutes in a 95% O₂/5% CO₂ humidified environment. At forty minutes post initiation of the incubation, the medium was discarded, and the cells were washed twice with cold incubation media. The cells were harvested from the wells following incubation in a trypsin/EDTA solution for five minutes at 37°C.
- 20 Subsequently, the radioactivity, per well, was determined and the maximum % total uptake of the radiolabeled peptide was determined and normalized to 100%. A similar procedure was used in performing cell

binding assays with both the PC-3 and CF_a-PAC-1 human cancer cell lines.

C. Results of Binding Affinity Measurements

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The IC₅₀ values measured for the BBN derivatives synthesized in accordance with this invention showed that appending a chelator via amino acid chain spacer groups via the N-terminal BBN-8 residue (i.e., Trp⁸) produced a variation of IC₅₀ values. For example, see 10 IC₅₀ values shown for BBN 96, 97, 98 and 101 in Figure 19. The observations are consistent with previous reports showing variable IC₅₀ values when derivatizing BBH(8-13) with a predominantly short chain of amino acid residues [Hoffken, 1994]. When the amino acid spacer groups used in BBN-98, 99 and 101 were appended between BBN(7-14) and the 15 [16]aneS₄ macrocycle, the IC₅₀'s were found to be surprisingly constant and in the 1-6 nM range for all three cell lines (i.e., see IC₅₀ values shown in Figure 19). These data suggest that using relatively simple spacer groups composed entirely of selected amino acid sequences to extend ligands some distance from the BBN region [e.g., BBN(8-14) can produce 20 derivatives that maintain binding affinities in the 1-6 nmolar range.

D. Cell Binding Studies with Rh-BBN-Conjugates

Results illustrated in Figure 20 show that when the corresponding RhCl_2 [16]ane S_4 complex was separated from Trp^8 on BBH(8-14) by the four different amino acid spacer groups (see Figure 20), the IC_{50} 's of all four analogues (i.e., BBN-97, -98, -99, -101) were between 0.73 and 5.29 nmolar with GRP receptors on the PC-3 and CF PAC-1 cell lines. The IC_{50} 's for these same Rh-BBN conjugates were somewhat higher with the Swiss 3T3 cell line (Figure 20). These data demonstrate that amino acid chain with spacer groups used to move the +1 charged Rh- S_4 -chelate away from the BBN binding region will result in a metallated BBN analogue with sufficiently high binding affinities to GRP receptors for *in vivo* tumor targeting applications.

Example VI: Synthesis and *in vitro* binding assessment of a $^{99\text{m}}$ Tc-labeled synthetic BBN analogue

A. Synthesis

Several tetradentate chelating frameworks have been used to form stable $^{99\text{m}}$ Tc or ^{188}Re labeled peptide and protein conjugates [Eckelman, 1995; Li et al., 1996b; Parker, 1990; Lister-James et al., 1997]. Many of these ligand systems contain at least one thiol (-SH)

donor group to maximize rates of formation and stability (both *in vitro* and *in vivo*) of the resultant Tc(V) or Re(V) complexes [Parker, 1990; Eckelman, 1995]. Results from a recent report indicates that the bifunctional chelating agent (BFCA) (dimethylglycyl-L-seryl-L-cysteinyglycinamide (N₃S-BFCA) is capable of forming a well-defined complex with ReO⁺³ and TcO⁺³ [Wong et al., 1997]. Since this ligand framework can be synthesized by SPPS techniques, this N₃S-BFCA was selected for use in forming of Tc-99m-BBN-analogue conjugates. Three different N₃S-BFCA conjugates of BBN(7-14) were synthesized (BBN-120, -121 and -122) as shown in Figure 21 by SPPS. BBN-120, BBN-121 and BBN-122 represent a series of analogues where the N₃S-BFCA is separated from the BBN(7-14) sequence by a 3, 5 and 8 carbon spacer groups (Figure 21). Each peptide was synthesized and purified using the SPPS and chromatographic procedures outlined in Example 1. The thiol group on cystein was protected using the ACM group, which is not cleaved during cleavage of these BBN-conjugates from the resin using TFA. The identity of BBN-120, -121 and -122 was confirmed by FAB mass spectrometry. Synthesis and purification of the N₃S-BFCA could also be readily accomplished using SPPS methods, followed by HPLC purification (see Example 1). The ACM group was used to protect the thiol group on cysteine during synthesis and cleavage from the resin.

B. *In Vitro* Binding Affinities

Synthesis of ^{99m}Tc -BBN-122 (Figure 22) was prepared by two methods [i.e., (1) by transchelation of $^{99m}\text{TcO}^{+3}$ from ^{99m}Tc -gluconate or (2) by formation of the “preformed” ^{99m}Tc -BFCA complex followed by -COOH activation with tetrafluorophenyl and subsequent reaction with the C₅-carbon spacer group appended to BBN(7-14)]. In both cases, the ^{99m}Tc -labeled peptide formed is shown in Figure 22. The structure of this Tc-BBN-122 conjugate was determined by using non-radioactive Re(the chemical congener of Tc). In these studies, the “preformed” ReO^{+3} complex with the N₃S-BFCA was prepared by reduction of ReO_4 ; with SnCl_2 in the presence of excess N₃S-BFCA dissolved in sodium phosphate buffered water at pH 6-6.5 by a method previously published [Wong et al., 1997]. After purification of the ReO -N₃S-BFCA complex, the structure of this chelate was shown (by Mass-Spect) to be identical to that previously reported [Wong et al., 1997].

The ReO -N₃-S-BFCA complex was converted to the activated trifluorophenyl (TFP) ester by adding 10 mg of the complex to 6 mg (dry) EDC and the 50 μl of TFP. After the solution was vortexed for

one minute, CH₃CN was added until disappearance of cloudiness. The solution was incubated for one hour at RT and purified by reversed-phase HPLC. To prepare the ReO-N₃S-BFCA complex BBN-122 conjugate (Figure 22), one μ l of the HPLC fraction containing the ReO-N₃S-BFCA complex was added to a solution containing 1 mg of the C₈-tethered BBN(7-14) peptide in 0.2 N NaHCO₃ at pH 9.0. After incubation of this solution for one hour at RT, the sample was analyzed and purified by reversed-phase HPLC. The yield of Re-BBN-122 was approximately 30-35%.

10

The method for preparation of the corresponding ^{99m}Tc-BBN-122 conjugate, using the "preformed" ^{99m}TcO-N₃S-BFCA complex, was the same as described above with the "preformed" ReO-N₃S-BFCA complex. In this case, ^{99m}TcO₄, from a ⁹⁹Mo/^{99m}Tc generator, was reduced with an aqueous saturated stannous tartrate solution in the presence of excess N₃S-BFCA. The yields of the ^{99m}Tc-BBN-122 product using this "preformed" method were approximately 30-40%. Reversed phase HPLC analysis of the ^{99m}Tc-BBN-122, using the same gradient elution program¹ as used for analysis of the Re-BBN-122 conjugate, showed that

¹ Gradient elution program used in these studies was as follows.

Flow 1.5 ml/minute

Solvent A = HO with 0.1% TFA

Solvent B = CHCN with 0.1% TFA

both the ^{99m}Tc -BBN-122 and ^{188}Re -BBN-122 had the same retention time (i.e., 14.2-14.4 min) (See Figure 22). This provides strong evidence that the structure of both the ^{99m}Tc -BBN-122 and Re-BBN-122 are identical.

The binding affinities of BBN-122 and Re-BBN-122 were assessed for GRP receptors on Swiss 3T3 cells, PC-3 cells and CFPAC-1 cells that express GRP receptors. The IC_{50} 's of each derivative was determined relative to (i.e., in competition with) ^{125}I -Tyr⁴-BBN (the K_d for ^{125}I -Tyr⁴-BBN for GRP receptors in Swiss 3T3 cells is reported to be $1.6 \pm 0.4 \text{ nM}$) [Zhu et al., 1991]. The cell binding assay methods used to measure the IC_{50} 's is standard and was used by techniques previously reported [Leban et al., 1994; Cai et al., 1994; Cai et al., 1992]. The methods used for determining IC_{50} 's with all GRP receptor binding of GRP receptors on all cell lines was similar and has been described previously for the other BBN-analogues and Rh-BBN analogues described in this document.

C. Results of Binding Affinity Measurements

The IC_{50} values measured for BBN-122 and Re-BBN-122 synthesized in accordance with this invention showed that appending an

<u>Time (minutes)</u>	<u>%A/%B</u>
0	95/5
25	30/70
35	95/5

8-carbon hydrocarbon chain spacer linked to the N_2S_1 -BFCA and the corresponding Re complex (i.e., Trp⁸) produced BBN conjugates with IC_{50} values in a 1-5 nmolar range (See Table A). When ^{99m}Tc -BBN-122 was incubated with these same cells, it was shown that \geq nmolar

- 5 concentrations of BBN displaced this ^{99m}Tc conjugate by $> 90\%$. This result demonstrates that ^{99m}Tc -BBN-122 has high and specific binding affinity for GRP receptors. These data suggest that using relatively simple spacer groups to extend the N_3S ligand framework and the corresponding Tc-or Re- N_3S_1 , complexes some distance from the BBN
- 10 binding region can produce derivatives that maintain binding affinities in the 1-5 nmolar range.

TABLE A.

Summary of IC₅₀ values for GRP receptor binding for the non-metallated BBN-122 conjugate or the Re-BBN-122 conjugate in two cell lines (PC-3 and CF-PAC-1 cell lines that express GRP receptors).

5 The IC₅₀ values were measured using cell binding assays relative to ¹²⁵I-Tyr⁴-BBN.

Conjugate	IC ₅₀ (nmolar)	
	PC-3	CF-PAC1
BBN-122	3.59 ± 0.75 (n=6)	5.58 ± 1.92 (n=14)
Re-BBN-122	1.23 ± 0.56 (n=12)	1.47 ± 0.11 (n=6)

Example VII: Retention of ^{99m}Tc -BBN-122 in Human Cancer Cells
PC-3 and CF-PAC-1 cells)

Once the radiometal has been specifically “delivered” to
5 cancer cells (e.g., employing the BBN binding moiety that specifically
targets GRP receptors on the cell surface), it is necessary that a large
percentage of the “delivered” radioactive atoms remain associated with
the cells for a period time of hours or longer to make an effective
radiopharmaceutical for effectively treating cancer. One way to achieve
10 this association is to internalize the radiolabeled BBN conjugates within
the cancer cell after binding to cell surface GRP receptors.

Experiments designed to determine the fraction ^{99m}Tc -
BBN-122 internalized within cells were performed by the same method
15 previously described for ^{105}Rh -BBN-37. Briefly, excess ^{99m}Tc -BBN-122
was added to PC-3 or CFPAC-1 cell incubation media and allowed to
establish equilibrium after a forty minute incubation. The media
surrounding the cells was removed and the cells were washed with fresh
media containing no radioactivity. After washing, the quantity of
20 radioactivity associated with the cells was determined (i.e., total counts
per min ^{99m}Tc associated with cells). The PC-3 and CFPAC-1 cells were
then incubated in a 0.2M acetic acid solution (pH2.5) which caused the

surface proteins (including GRP receptors) to denature and release all surface bound radioactive materials. After removing this buffer and washing, the cells were counted again. The counts per minute (c.p.m.) associated with the cells at that point were only related to the ^{99m}Tc that
5 remained trapped inside of the PC-3 or CFPAC-1 cells.

To determine intracellular retention of ^{99m}Tc activity, a similar method was employed. However, after washing the cells with fresh (non-radioactive) incubation media, the cells were incubated in the
10 fresh media at different time period after washing away all extracellular ^{99m}Tc -BBN-122. After each time interval, the methods used to determine total c.p.m. and intracellular c.p.m. by washing with a 0.2M acetic acid solution at pH 2.5.

15 Studies with the ^{99m}Tc -BBN-122 agonist show that it is internalized inside of the PC-3 and CFPAC-1 cells (Figures 23-26) and that substantial intracellular retention of ^{99m}Tc by the GRP receptor expressing cells occurs. For example, results of studies using ^{99m}Tc -BBN-122 in conjunction with PC-3 cells showed a high rate of internalization
20 (Figure 23) and that approximately 75% of the ^{99m}Tc activity remains

associated with the cells at ninety minutes post-washing (Figure 25).

Almost all of this ^{99m}Tc cell-associated activity is inside of the PC-3 cells.

Similar results were also found with the CFPAC 1 cells where there is

also a high rate of ^{99m}Tc -BBN-122 internalization (Figure 24) and

5 relatively slow efflux of ^{99m}Tc from the cells (i.e., 50-60% retention at 120 min post-washing (Figure 26).

The ^{99m}Tc -BBN-122 peptide conjugate shown in Figure 22 has an amidated methionine at position BBN-14 and is expected to be an
10 agonists [Jensen et al., 1993]. Therefore, it would be predicted to rapidly internalize after binding to GRP receptors on the cell surface [Bjisterbosch et al., 1995; Smythe et al., 1991], which is confirmed by applicants' data in Figure 23-26.

15 Example VIII: *In Vivo* Studies

Biodistribution studies were performed by intravenous (I.V.) injection of ^{99m}Tc -BBN-122 into normal mice. In these studies, unanesthetized CF-1 mice (15-22g, body wt.) were injected I.V. via the

tail vein with between one (1) to five (5) μCi (37-185 KBq) of $^{99\text{m}}\text{Tc}$ -BBN-122. Organs, body fluids and tissues were excised from animals sacrificed at 0.5, 1, 4 and 24 hours post-injection (PI). The tissues were weighed, washed in saline (when appropriate) and counted in a NaI well
5 counter. These data were then used to determine the percent injected dose (% ID) in an organ or fluid and the % ID) per gram. The whole blood volume of each animal was estimated to be 6.5 percent of the body weight. Results of these studies are summarized in Tables B and C.

10 Results from these studies showed that $^{99\text{m}}\text{Tc}$ -BBN-122 is cleared from the blood stream predominantly via the hepatobiliary pathway shaving about 35% of the $^{99\text{m}}\text{Tc}$ -activity cleared via the kidney into the urine. Specifically, $33.79 \pm 1.76\%$ of the ID was found in urine at one hour PI (Table B). The retention of $^{99\text{m}}\text{Tc}$ activity in the kidneys and
15 liver is very low (Table B). This is much less than would be expected from previously reported data where radiometallated peptides and small proteins have exhibited renal retention of the radiometal that is $> 10\%$ ID and usually much $> 10\%$ [Duncan et al., 1997]. The reason for reduced renal retention of $^{99\text{m}}\text{Tc}$ -BBN-122 is not known, however, this result
20 demonstrates a substantial improvement over existing radiometallated peptides.

Biodistribution studies also demonstrated another important *in vivo* property of ^{99m}Tc -BBN-122 in that it is efficiently cleared from organs and tissues that do not express GRP receptors (or those that do not have their GRP-receptors accessible to circulating blood). The biodistribution studies in mice demonstrated specific uptake of ^{99m}Tc -BBN-122 in the pancreas while other non-excretory organs or tissues (i.e., heart, brain, lung, muscle, spleen) exhibited no uptake or retention. ^{99m}Tc -BBN-122 is removed from the blood stream by both the liver and kidneys with a large fraction of the ^{99m}Tc removed by these routes being excreted into the intestines and the bladder, respectively. It is important to note that the % ID/gm in the pancreas of ^{99m}Tc -BBN-122 is 12.63%/gm at 1 hour and drops to only 5.05% at the 4 hour PI (Table C). Thus, the ratios of % ID/gm of ^{99m}Tc -BBN-122 in the pancreas relative to muscle and blood were 92.2 and 14.78 at 4 hour PI, respectively. These data demonstrated selective *in vivo* targeting of this ^{99m}Tc -labeled BBN analogue to cells expressing GRP receptors [Zhu et al., 1991; Qin et al., 1994] and efficient clearance from non-target tissues. If cancer cells that express GRP receptors are present in the body, these results indicate ^{99m}Tc -BBN analogues will be able to target them with a selectivity similar to the pancreatic cells.

Table B. Biodistribution of ^{99m}Tc -BBN-122 in normal CF-1 mice at 0.5, 1, 4 and 24 hr post-IV injection. Results expressed as % ID/organ

Organ ^c	% Injected Dose/Organ ^a			
	30 min	1 hr	4 hr	24 hr
Blood ^d	3.52 \pm 2.16	1.08 \pm 0.34	0.59 \pm 0.24	0.12 \pm 0.01
Liver	4.53 \pm 0.93	4.77 \pm 1.40	1.49 \pm 0.32	0.32 \pm 0.06
Stomach	2.31 \pm 0.45	1.61 \pm 0.81	1.75 \pm 0.20	0.30 \pm 0.06
Lg. Intestine ^b	2.84 \pm 0.32	24.17 \pm 7.91	23.85 \pm 7.02	0.61 \pm 0.14
Sm. Intestine ^b	43.87 \pm 1.51	23.91 \pm 9.08	5.87 \pm 7.09	0.42 \pm 0.06
Kidneys ^b	1.49 \pm 0.19	1.15 \pm 0.10	0.55 \pm 0.06	0.20 \pm 0.01
Urine ^b	26.78 \pm 1.05	33.79 \pm 1.76	~35	~35
Muscle	0.02 \pm 0.01	0.01 \pm 0.00	0.01 \pm 0.01	0.01 \pm 0.01
Pancreas	5.30 \pm 0.63	3.20 \pm 0.83	1.21 \pm 0.13	0.42 \pm 0.17

- Each value in the table represents the mean and SD from 5 animals in each group.
- At 4 and 24 hr, feces containing ^{99m}Tc had been excreted from each animal and the % ID in the urine was estimated to be approximately 60% of the ID.
- All other organs excised (incl. brain, heart, lung and spleen) showed $< 0.10\%$ at $t \geq 1$ hr.
- % ID in the blood estimated assuming the whole blood volume is 6:5% of the body weight.

Table C. Biodistribution of ^{99m}Tc -BBN-122 in normal CF-1 mice at 0.5, 1, 4 and 24 hr post I.V. injection. Results expressed as % ID/gm.

Organ	% Injected Dose/gm ^a			
	30 min	1 hr	4 hr	24 hr
Blood ^b	2.00 \pm 1.28	0.63 \pm 0.19	0.34 \pm 0.11	0.08 \pm 0.00
Liver	2.70 \pm 0.41	3.14 \pm 0.81	0.96 \pm 0.20	0.22 \pm 0.05
Kidneys	3.99 \pm 0.76	3.10 \pm 0.31	1.58 \pm 0.15	0.64 \pm 0.08
Muscle	0.23 \pm 0.08	0.13 \pm 0.02	0.05 \pm 0.01	0.01 \pm 0.01
Pancreas	16.89 \pm 0.95	12.63 \pm 1.87	5.05 \pm 0.42	1.79 \pm 0.71
P/Bl and P/M Uptake Ratios				
Pancreas/Blood	8.42	19.76	14.78	20.99
Pancreas/Muscle	73.16	93.42	92.25	142.76

- a. Each value in the table represents the mean and SD from 5 animals in each group.
b. % ID in the blood estimated assuming the whole blood volume is 6.5% of the body weight.

Table D. Biodistribution of ^{99m}Tc -BBN-122 in PC-3 tumor bearing SCID mice at 1, 4 and 24 hr post-I.V. injection. Results expressed as % ID/organ.

Tumor Line: PC-3	% ID per Organ ^a		
Organ ^c	1 hr	4 hr	24 hr
Blood ^b	1.16 \pm 0.27	0.47 \pm 0.06	0.26 \pm 0.05
Liver	1.74 \pm 0.64	0.72 \pm 0.10	0.29 \pm 0.05
Stomach	0.43 \pm 0.18	0.29 \pm 0.22	0.08 \pm 0.02
Lg. Intestine	9.18 \pm 19.42	42.55 \pm 8.74	0.64 \pm 0.17
Sm. Intestine	46.55 \pm 16.16	2.13 \pm 0.76	0.31 \pm 0.04
Kidneys	1.16 \pm 0.20	0.60 \pm 0.06	0.16 \pm 0.01
Urine ^d	32.05 \pm 12.78	~ 35	~ 35
Muscle	0.01 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
Pancreas	1.69 \pm 0.61	1.05 \pm 0.13	0.34 \pm 0.08
Tumor	1.00 \pm 0.78	0.49 \pm 0.08	0.49 \pm 0.25

- Each value in the table represents the mean and SD from 5 animals in each group.
- At 4 and 24 hr, feces containing ^{99m}Tc had been excreted from each animal and the % ID in the urine was estimated to be approximately 60% of the ID.
- All other organs excised (incl. brain, heart, lung and spleen) showed < 0.10% at $t \geq 1$ hr.
- % ID in the blood estimated assuming the whole blood volume is 6.5% of the body weight.

Table E. Biodistribution of ^{99m}Tc -BBN-122 in PC-3 tumor bearing SCID mice at 1, 4 and 24 hr post-I.V. injection. Results expressed as % ID/Gm.

Tumor Line: PC-3	% ID per gm ^a		
Organ	1 hr	4 hr	24 hr
Blood ^b	0.97 ± 0.26	0.31 ± 0.03	0.18 ± 0.04
Liver	2.07 ± 0.88	0.64 ± 0.05	0.26 ± 0.04
Kidneys	4.80 ± 1.33	2.23 ± 0.35	0.60 ± 0.04
Muscle	0.18 ± 0.12	0.06 ± 0.03	0.05 ± 0.04
Pancreas	10.34 ± 3.38	5.08 ± 1.12	1.47 ± 0.23
Tumor	2.07 ± 0.50	1.75 ± 0.61	1.28 ± 0.22
T/Bl, T/M, P/Bl and P/M Uptake Ratios			
Tumor/Blood	2.13	5.52	6.79
Tumor/Muscle	11.44	25.38	21.62
Pancreas/Blood	10.64	15.96	7.81
Pancreas/Muscle	57.14	73.40	24.87

- a. Each value in the table represents the mean and SD from 5 animals in each group.
b. % ID in the blood estimated assuming the whole blood volume is 6.5% of the body weight.

The invention has been described in an illustrative manner, and it is to be understood that the terminology which has been used is intended to be in the nature of words of description rather than of limitation.

5 Obviously, many modifications and variations of the present invention are possible in light of the above teachings. It is, therefore, to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically describe.

10 Throughout this application, various publications are referenced by citation and number. Full citations for the publication are listed below. the disclosure of these publications in their entirety are hereby incorporated by reference into this application in order to more fully describe the state of the art to which this invention pertains.

15

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Table 1

Binding Affinity of Rh-BBN-37 for GRP Receptors Expressed on Neoplasms

Type of Cancer	Cell Line	IC ₅₀ (Mean Value)
Pancreatic CA	CF PAC1	3.2 X 10 ⁻⁹
Prostate CA	PC-3	7.0 X 10 ⁻⁹

Table 2
(%Dose)

Complex	¹⁰⁵ Rh-Peptide22 30 min n=9	¹⁰⁵ Rh-Peptide22 1 hr n=9	¹⁰⁵ Rh-Peptide22 2 hr n=9
Organ (%Dose)			
Brain	0.08 ±	0.04 ±	0.06 ±
Blood	4.48 ±	1.86 ±	0.99 ±
Heart	0.13 ±	0.08 ±	0.04 ±
Lung	0.25 ±	0.20 ±	0.15 ±
Liver	7.97 ±	8.51 ±	8.57 ±
Spleen	0.07 ±	0.09 ±	0.05 ±
Stomach	1.11 ±	0.59 ±	0.30 ±
Large Intestine	0.73 ±	3.21 ±	8.91 ±
Small Intestine	6.29 ±	6.98 ±	3.48 ±
Kidneys	4.25 ±	3.25 ±	2.44 ±
Bladder	44.66 ±	62.88 ±	68.41 ±
Muscle	0.06 ±	0.03 ±	0.01 ±
Pancreas	0.95 ±	1.15 ±	1.01 ±
Carcass	32.90 ±	12.62 ±	6.37 ±

Table 2 (continued)
(%Dose/Gm)

Complex	105 Rh-Peptide22 30 min n=9	105 Rh-Peptide22 1 hr n=9	105 Rh-Peptide22 2 hr n=9
Organ (%D/GM)			
Brain	0.21 ± 0.07	0.14 ± 0.08	0.16 ± 0.28
Blood	2.22 ± 0.40	1.02 ± 0.22	0.51 ± 0.11
Heart	0.92 ± 0.25	0.64 ± 0.20	0.38 ± 0.33
Lung	1.44 ± 0.33	1.24 ± 0.54	0.92 ± 0.69
Liver	4.33 ± 1.52	5.18 ± 1.52	5.17 ± 1.12
Spleen	0.86 ± 0.38	1.10 ± 0.65	0.84 ± 0.53
Stomach	2.46 ± 1.65	1.53 ± 0.74	0.71 ± 0.33
Large Intestine	0.78 ± 0.19	4.42 ± 4.62	10.10 ± 4.58
Small Intestine	4.73 ± 1.47	5.84 ± 1.81	2.86 ± 1.47
Kidneys	7.57 ± 1.49	6.70 ± 0.75	4.60 ± 0.83
Muscle	0.53 ± 0.32	0.61 ± 0.97	0.24 ± 0.24
Pancreas	3.12 ± 0.99	4.31 ± 1.98	3.88 ± 1.25

Table 3
(%Dose)

Complex	¹⁰⁵ Rh-Pept37 30 min n=5	¹⁰⁵ Rh-Pept37 1 hr n=9	¹⁰⁵ Rh-Pept37 2 hr n=7
Organ (%Dose)			
Brain	0.03 ±	0.07 ±	0.03 ±
Blood	3.09 ±	1.46 ±	0.66 ±
Heart	0.12 ±	0.05 ±	0.04 ±
Lung	0.26 ±	0.12 ±	0.08 ±
Liver	13.04 ±	13.00 ±	10.12 ±
Spleen	0.21 ±	0.16 ±	0.10 ±
Stomach	0.80 ±	0.65 ±	0.83 ±
Large Intestine	2.05 ±	2.96 ±	8.07 ±
Small Intestine	8.44 ±	11.38 ±	5.04 ±
Kidneys	7.82 ±	6.04 ±	4.57 ±
Bladder	39.65 ±	51.82 ±	62.32 ±
Muscle	0.06 ±	0.02 ±	0.02 ±
Pancreas	2.73 ±	3.63 ±	2.25 ±
Carcass	24.35 ±	9.81 ±	6.37 ±

Table 3 (continued)
(%Dose/Gm)

Complex	¹⁰⁵ Rh-Pept37 30 min n=5	¹⁰⁵ Rh-Pept37 1 hr n=9	¹⁰⁵ Rh-Pept37 2 hr n=7
Organ (%D/GM)			
Brain	0.10 ± 0.05	0.26 ± 0.41	0.10 ± 0.09
Blood	1.60 ± 0.30	0.72 ± 0.31	0.34 ± 0.15
Heart	0.92 ± 0.26	0.38 ± 0.21	0.28 ± 0.17
Lung	1.52 ± 0.48	0.76 ± 0.47	0.46 ± 0.50
Liver	7.31 ± 1.15	7.65 ± 1.29	6.30 ± 1.73
Spleen	2.18 ± 1.17	1.59 ± 0.71	1.05 ± 0.44
Stomach	1.53 ± 0.67	1.63 ± 1.17	2.18 ± 2.35
Large Intestine	2.46 ± 0.70	3.80 ± 2.42	11.84 ± 4.39
Small Intestine	5.69 ± 1.26	7.85 ± 1.87	3.81 ± 2.01
Kidneys	14.28 ± 2.84	11.21 ± 3.68	8.39 ± 2.36
Muscle	0.73 ± 0.39	0.20 ± 0.14	0.39 ± 0.38
Pancreas	14.02 ± 3.23	15.54 ± 6.21	9.91 ± 5.35

CLAIMS

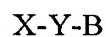
What is claimed is:

- 5 1. A compound for use as a therapeutic or diagnostic
radiopharmaceutical, said compound comprising a group capable of
complexing a metal attached to a moiety capable of binding to a gastrin
releasing peptide (GRP) receptor.
- 10 2. A compound as set forth in claim 1, wherein said moiety
capable of binding to a gastrin releasing peptide receptor is a gastrin
releasing peptide receptor agonist.
- 15 3. A compound as set forth in claim 2, wherein said gastrin
releasing peptide receptor agonist includes a bombesin agonist binding
moiety.
4. A compound as set forth in claim 1, wherein said group
capable of complexing a metal includes a chelating group.

20

5. A compound as set forth in claim 4, wherein said chelating group is attached to said bombesin agonist binding moiety by a spacer group.

5 6. A compound as set forth in claim 5 having a structure of the formula:



wherein X is said group capable of complexing a metal; Y is said spacer group or covalent bond; and B is a bombesin agonist binding moiety.

10

7. A compound as set forth in claim 6, wherein Y is a C₁-C₁₀ hydrocarbon chain.

8. A compound as set forth in claim 7, wherein Y is a C₃-C₉ hydrocarbon chain.

15

9. A compound as set forth in claim 6, wherein Y includes at least one amino acid residue.

20 10. A compound as set forth in claim 9, wherein Y includes a L-Gln residue at the BBN-7 position.

11. A compound as set forth in claim 5, wherein said chelating group is attached to said bombesin agonist binding moiety at the N-terminal end of a peptide bombesin binding moiety.

5 12. A compound as set forth in claim 11, wherein said chelating group is attached to said peptide bombesin agonist binding moiety at amino acid residue 8 (trp⁸) of said bombesin agonist binding moiety.

10 13. A compound as set forth in claim 11, wherein said spacer is attached to said bombesin agonist binding moiety at the N-terminal end of said bombesin agonist binding moiety.

14. A compound as set forth in claim 13, wherein said spacer
15 is attached to said bombesin agonist binding moiety at amino acid residue 8 (D⁻ or L⁻ trp⁸) of said bombesin agonist binding moiety.

15. A compound as set forth in claim 1, wherein said metal is a diagnostically or therapeutically useful metal.

20

16. A compound as set forth in claim 15, wherein said transition metal is a metallic radioisotope selected from the group including γ and β emitting isotopes.

5 17. A compound as set forth in claim 16, wherein said metallic radioisotope is a radionuclide selected from the group including ^{186}Re , ^{188}Re , $^{99\text{m}}\text{Tc}$, ^{105}Rh , ^{199}Au , ^{153}Sm , ^{166}Ho and ^{90}Y .

18. A method as set forth in claim 16, wherein said metallic
10 isotope includes oxides and nitrides thereof.

19. A compound as set forth in claim 4 wherein said chelating agent includes a multidentate chelating structure capable of forming a highly stable complex with metals via coordinating atoms.

15

20. A compound as set forth in claim 19, wherein said chelating structure includes coordinating atoms S, N, O, or P.

21. A compound as set forth in claim 19, wherein said
20 chelating structure is a macrocyclic compound including coordinating atoms.

22. A compound as set forth in claim 19, wherein said chelating structure is a S_4 chelator.

23. A compound as set forth in claim 19, wherein said
5 compound is a N_4 chelator.

24. A compound as set forth in claim 19, wherein said compound is a N_2S_2 chelator.

10 25. A compound as set forth in claim 19, wherein said compound is a NS_3 chelator.

26. A compound as set forth in claim 19, wherein said compound is a N_3S chelator.

15

27. A compound as set forth in claim 3, wherein said compound has a binding affinity for the gastrin releasing peptide receptor that is approximately equal to or greater than that of native bombesin.

20

28. A method for treating a subject having a neoplastic disease, said method comprising the steps of:

administering to the subject an effective amount of a pharmaceutical comprising a metal complexed with a chelating group attached to a moiety capable of specifically binding to a gastrin releasing peptide receptor.

5

29. A method as set forth in claim 28, wherein the moiety capable of binding to a gastrin releasing peptide receptor is a gastrin releasing peptide receptor agonist.

10

30. A method as set forth in claim 28 further including the step of contacting the radiopharmaceutical with a neoplastic cell.

15

31. A method as set forth in claim 30, wherein said contacting step is further defined as binding the radiopharmaceutical to gastrin releasing peptide receptors expressed on the neoplastic cell.

20

32. A method as set forth in claim 28 further including the step of internalizing the compound into the neoplastic cell.

33. A method as set forth in claim 28 further including the step of retaining the compound within the neoplastic cell for a period of time

sufficient to initiate death of the neoplastic cell or provide a diagnostic image of the tumors.

34. A method as set forth in claim 29, wherein the gastrin
5 releasing peptide receptor agonist includes a bombesin agonist binding moiety.

35. A method as set forth in claim 34, wherein the chelated
metal is attached to the bombesin agonist binding moiety by a spacer
10 group.

36. A method as set forth in claim 34, wherein the compound
has the structure of the formula:



15 wherein X is the group capable of binding a metal; Y is the spacer group
or a covalent bond and B is a bombesin agonist binding moiety.

37. A method forth in claim 36, wherein Y is a C₁-C₁₀
hydrocarbon chain.

20

38. A method as set forth in claim 37, wherein Y is a C₃-C₉
hydrocarbon chain.

39. A method as set forth in claim 36, wherein Y includes at least one amino acid residue.

5 40. A method set forth in claim 39, wherein Y includes a L-Gln residue at the BBN-7 position.

41. A method as set forth in claim 36, wherein the chelating group is attached to peptide bombesin agonist binding moiety at the
10 N-terminal end of the bombesin agonist binding moiety.

42. A method as set forth in claim 41, wherein the chelating group is attached to the bombesin agonist binding moiety to amino acid residue 8 (D⁻ or L⁻ trp⁸) of the bombesin agonist binding moiety.
15

43. A method as set forth in claim 41, wherein the spacer is attached to the bombesin agonist binding moiety at the N-terminal end of the bombesin agonist binding moiety.

20 44. A method as set forth in claim 28, wherein the transition metal is a diagnostically or therapeutically useful radioactive metal.

45. A method as set forth in claim 44, wherein the metal is a metallic radioisotope selected from the group including γ and β emitting isotopes.

5 46. A method as set forth in claim 45, wherein the metallic radioisotope is a radionuclide selected from the group including ^{186}Re , ^{188}Re , $^{99\text{m}}\text{Tc}$, ^{105}Rh , ^{199}Au , ^{153}Sm , ^{166}Ho and ^{90}Y .

47. A method as set forth in claim 46, wherein said metallic
10 radioisotope includes oxides and nitrides thereof.

48. A compound as set forth in claim 28 wherein said chelating agent includes a multidentate chelating structure capable of forming a highly stable complex with metals via coordinating atoms.

15

49. A method as set forth in claim 48, wherein said chelating structure includes coordinating atoms S, N, O, or P.

50. A method as set forth in claim 48, wherein the chelating
20 structure is a macrocyclic compound including coordinating atoms.

51. A method as set forth in claim 48, wherein said compound is a S_4 chelator.

52. A method as set forth in claim 48, wherein said compound is a N_4 chelator.

53. A method as set forth in claim 48, wherein said compound is a N_2S_2 chelator.

54. A method as set forth in claim 48, wherein said compound is a NS_3 chelator.

55. A method as set forth in claim 48, wherein said compound is a N_3S chelator.

56. A method as set forth in claim 28, wherein the compound has a binding affinity for the gastrin releasing peptide receptor that is approximately equal to or greater than that of native bombesin.

57. A method of forming a therapeutic or diagnostic compound comprising the step of reacting a metal complexed with a chelating group

with a moiety capable of agonistic binding a gastrin releasing peptide receptor.

58. A method of forming a therapeutic or diagnostic compound
5 comprising a step of reacting a metal with a chelating group already
covalently attached to a moiety capable of agonistic binding a gastrin
releasing peptide receptor.

59. A method as set forth in claim 57, wherein the moiety
10 capable of binding to a gastrin releasing peptide receptor is a gastrin
releasing peptide receptor agonist.

60. A method as set forth in claim 57, wherein the gastrin
releasing peptide receptor agonist includes a bombesin agonist binding
15 moiety.

61. A method as set forth in claim 60, wherein the chelated
metal is attached to the bombesin agonist binding moiety by a spacer
group.

20

62. A method as set forth in claim 60, wherein the compound
has the structure of the formula:



wherein X is the group capable of binding a metal; Y is the spacer group or a covalent bond and B is a bombesin binding moiety.

5 63. A method forth in claim 62, wherein Y is a C₁-C₁₀ hydrocarbon chain.

 64. A method as set forth in claim 63, wherein Y is a C₃-C₉ hydrocarbon chain.

10

 65. A method as set forth in claim 60, wherein Y includes at least one amino acid residue.

 66. A method as set forth in claim 65, wherein Y includes a L-
15 Gln residue at the BBN-7 position.

 67. A method as set forth in claim 62, wherein the chelating group is attached to the bombesin agonist binding moiety at the N-terminal end of the bombesin agonist binding moiety.

20

68. A method as set forth in claim 60, wherein the chelating group is attached to the bombesin agonist binding moiety at amino acid residue 8 (D⁻ or L⁻ trp⁸) of the bombesin molecule or derivative thereof.

5 69. A method as set forth in claim 60, wherein the spacer is attached to the bombesin agonist binding moiety at the N-terminal end of the bombesin agonist binding moiety.

70. A method as set forth in claim 60, wherein the spacer is
10 attached to the bombesin agonist binding moiety at amino acid residue 8 (D⁻ or L⁻ trp⁸) of the bombesin agonist binding moiety.

71. A method as set forth in claim 57, wherein the metal is a diagnostically or therapeutically useful radioactive metal.

15

72. A method as set forth in claim 71, wherein the metal is a metallic radioisotope selected from the group including γ and β emitting isotopes.

20 73. A method as set forth in claim 72, wherein the metallic radioisotope is a radionuclide selected from the group including ¹⁸⁶Re, ¹⁸⁸Re, ^{99m}Tc, ¹⁰⁵Rh, ¹⁹⁹Au, ¹⁵³Sm, ¹⁶⁶Ho and ⁹⁰Y.

74. A method as set forth in claim 73, wherein said metallic isotope includes oxides and nitrides thereof.
- 5 75. A method as set forth in claim 57, wherein said chelating agent includes a multidentate chelating structure capable of forming a highly stable complex with metals via coordinating atoms.
76. A method as set forth in claim 75, wherein said chelating
10 structure includes the coordinating atoms S, N, O, or P.
77. A method as set forth in claim 75, wherein the chelating structure is a macrocyclic compound including coordinating atoms.
- 15 78. A method as set forth in claim 75, wherein said compound is a S_4 chelator.
79. A method as set forth in claim 75, wherein said compound
is a N_4 chelator.
- 20 80. A method as set forth in claim 75, wherein said compound is a N_2S_2 chelator.

81. A method as set forth in claim 75, wherein said compound is a NS_3 chelator.

5 82. A method as set forth in claim 75, wherein said compound is a N_3S chelator.

83. A method as set forth in claim 57, wherein the compound has a binding affinity for the gastrin releasing peptide receptor that is
10 approximately equal to or greater than that of native bombesin.

84. A method of imaging a tumor site by administering to a subject a diagnostically effective amount of a compound as set forth in claim 1.

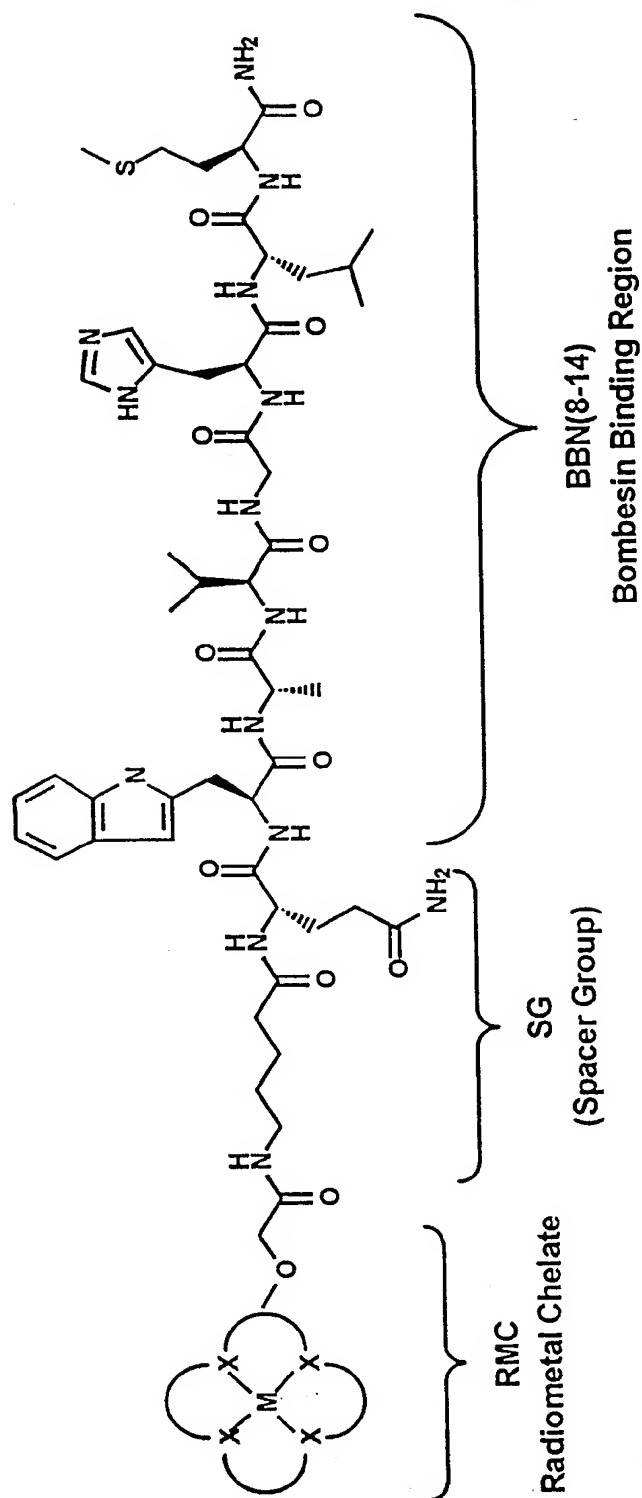
15

85. A method of formulation a pharmaceutical using a kit type method wherein the metal is added to a sealed vial containing a predetermined quantity of a compound described in claim 1 and a reducing agent.

20

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Radiometal Conjugate



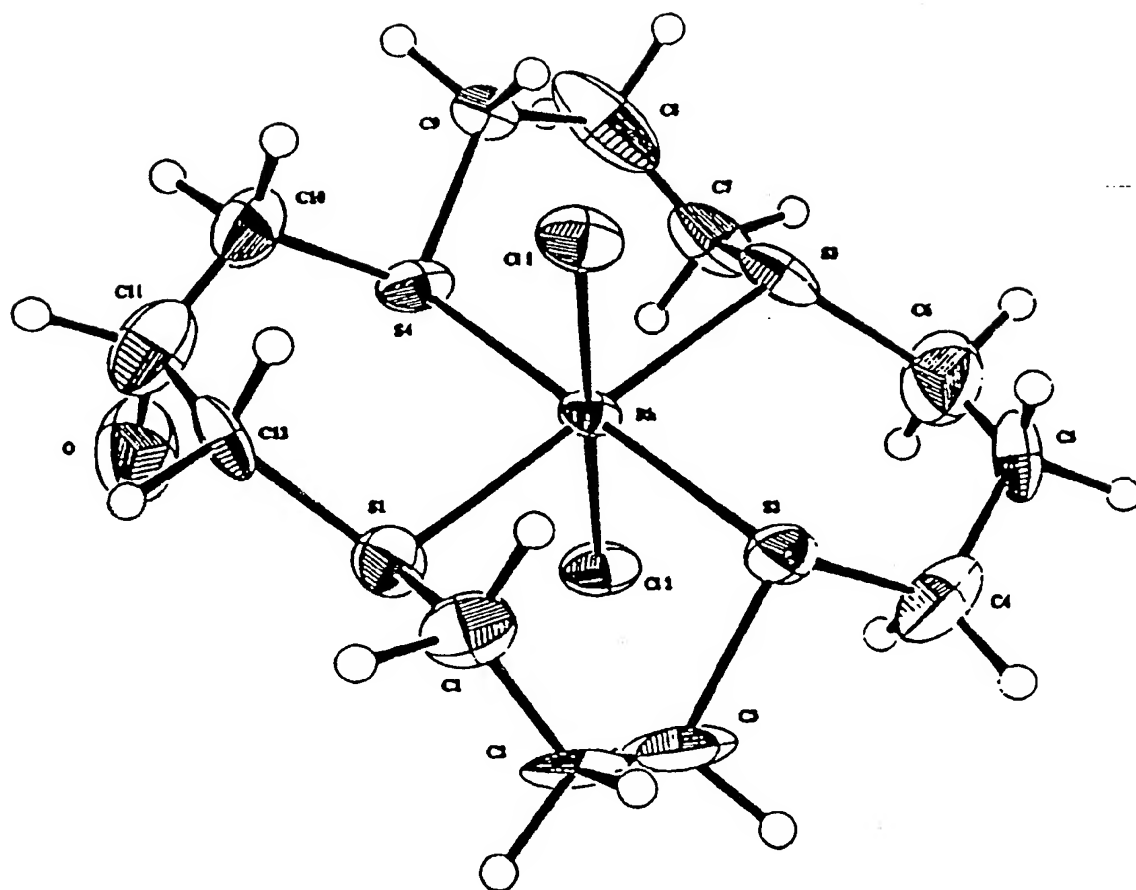
Radiometal conjugate of a BBN analogue that has high affinity for GRP receptors.

RMC=Radiometal chelate, where $M = {}^{99m}\text{Tc}$, ${}^{186/188}\text{Re}$, ${}^{105}\text{Rh}$ and X =chelating atoms.

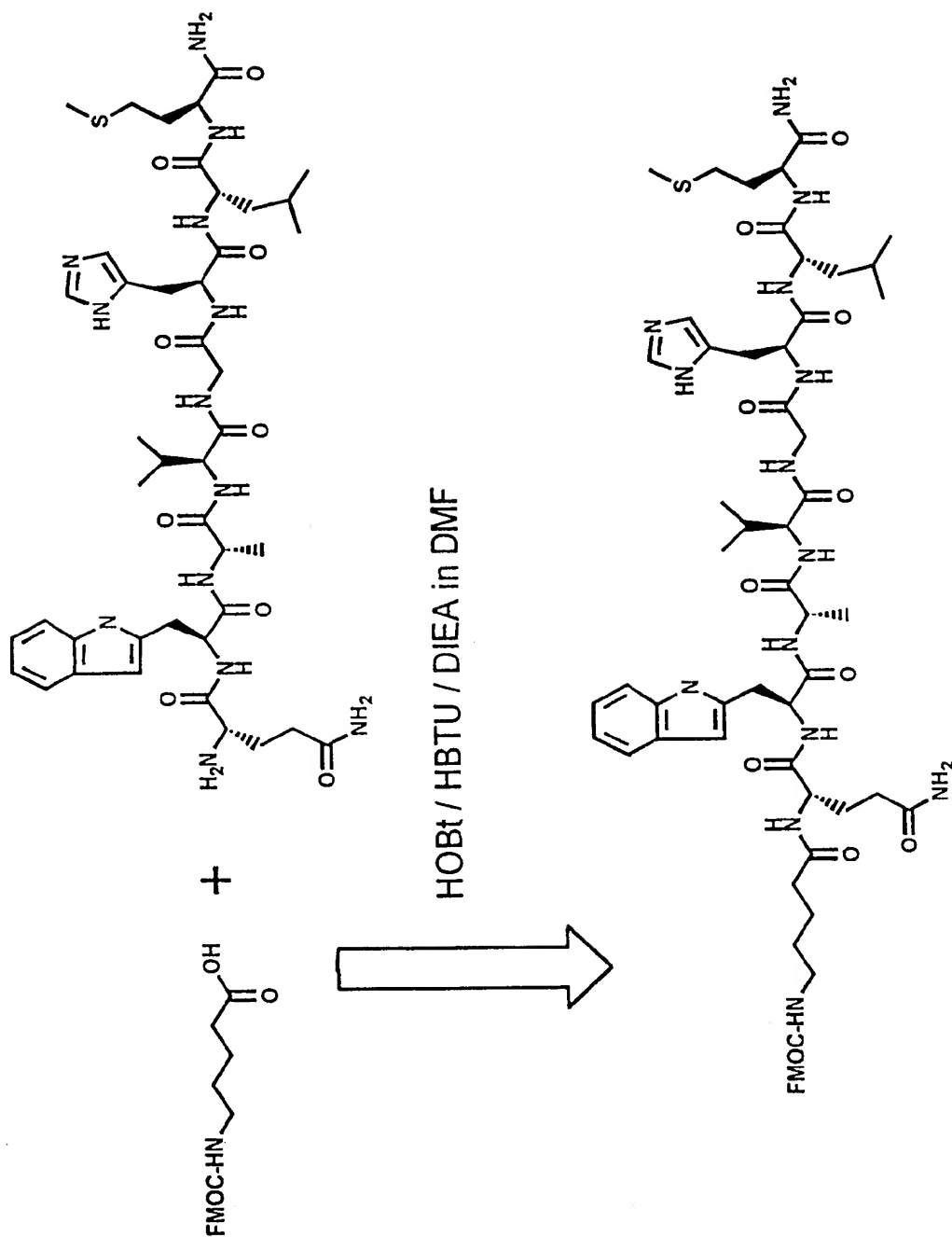
SG=Spacer group or linker that covalently attaches the chelate to the N-terminal end of the BBN binding region (BBN_{BR})

Figure 1

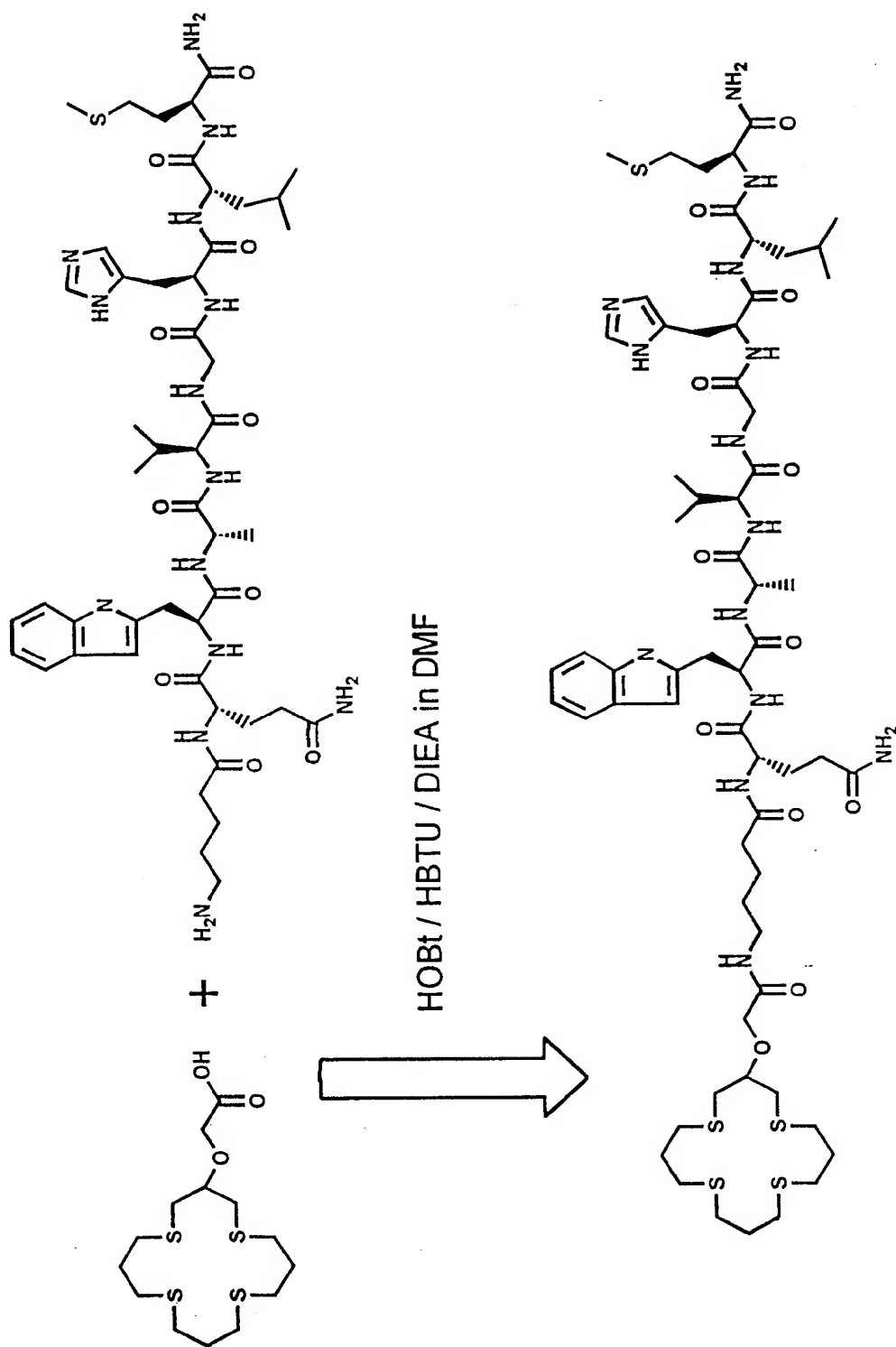
2/26

ORTEP Drawing of {Rh[16]aneS₄-olCl₂}⁺Figure 2

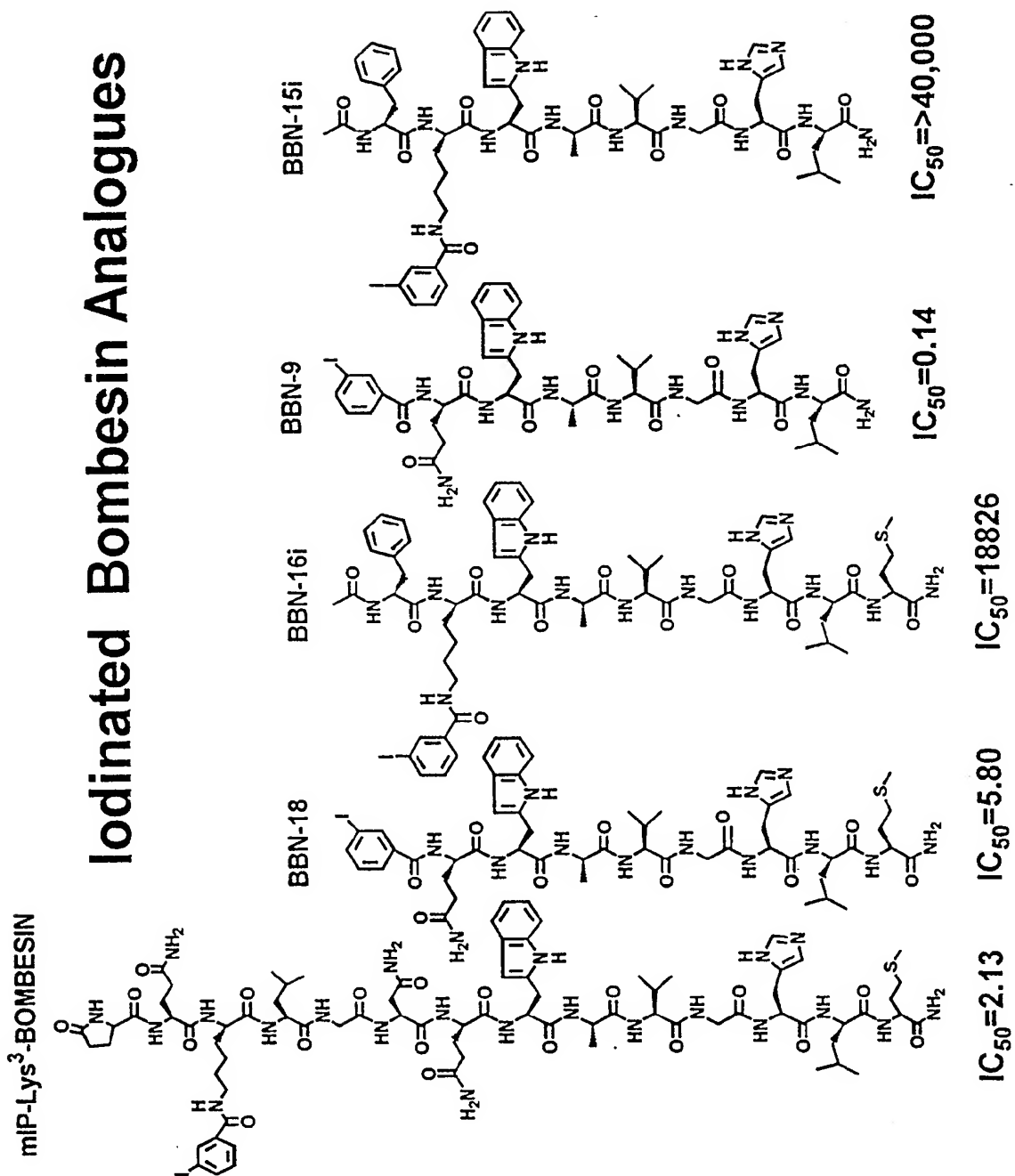
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Figure 3

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Figure 4

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Figure 5

Tethered Bombesin Analogues

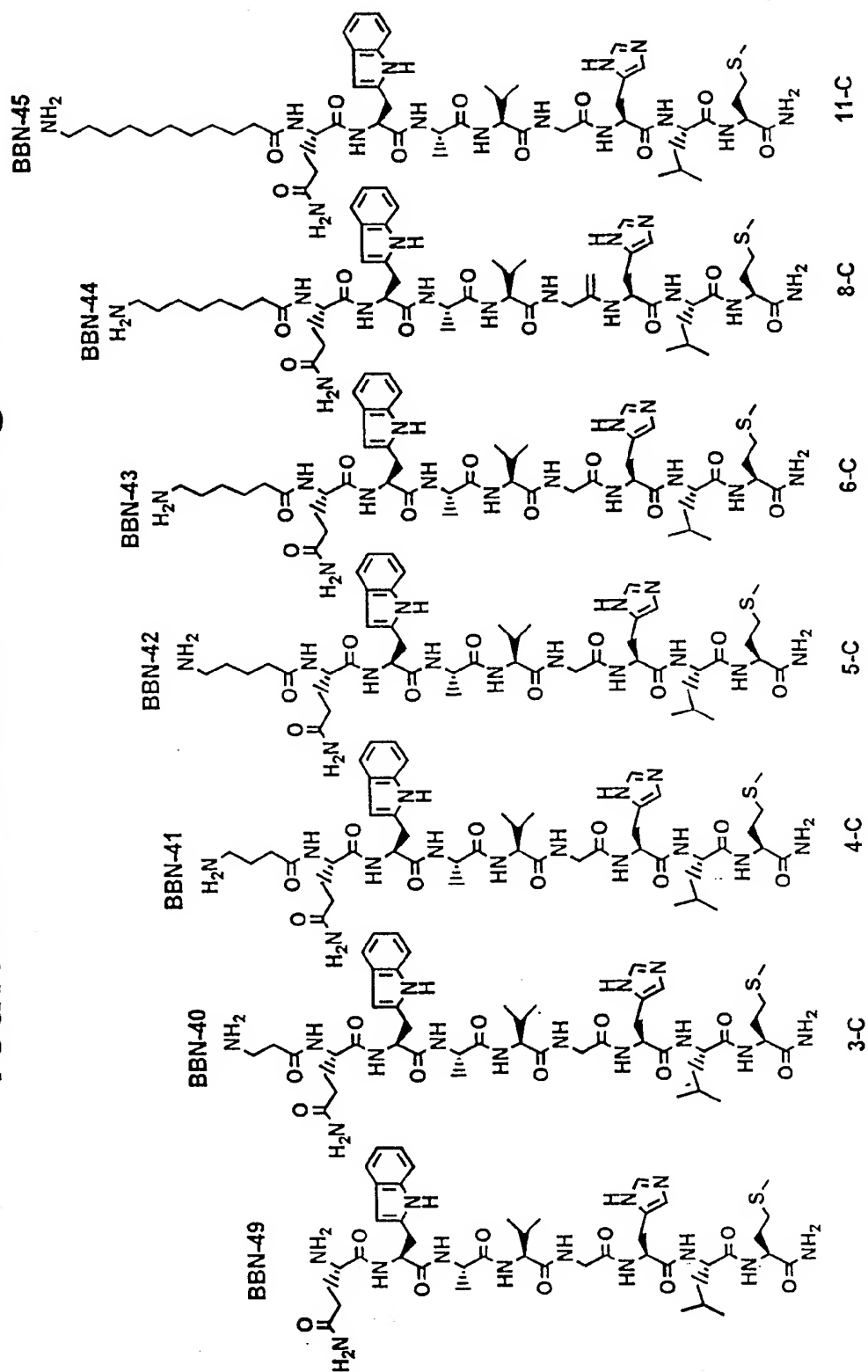


Figure 6

[16]aneS₄ Bombesin Analogues

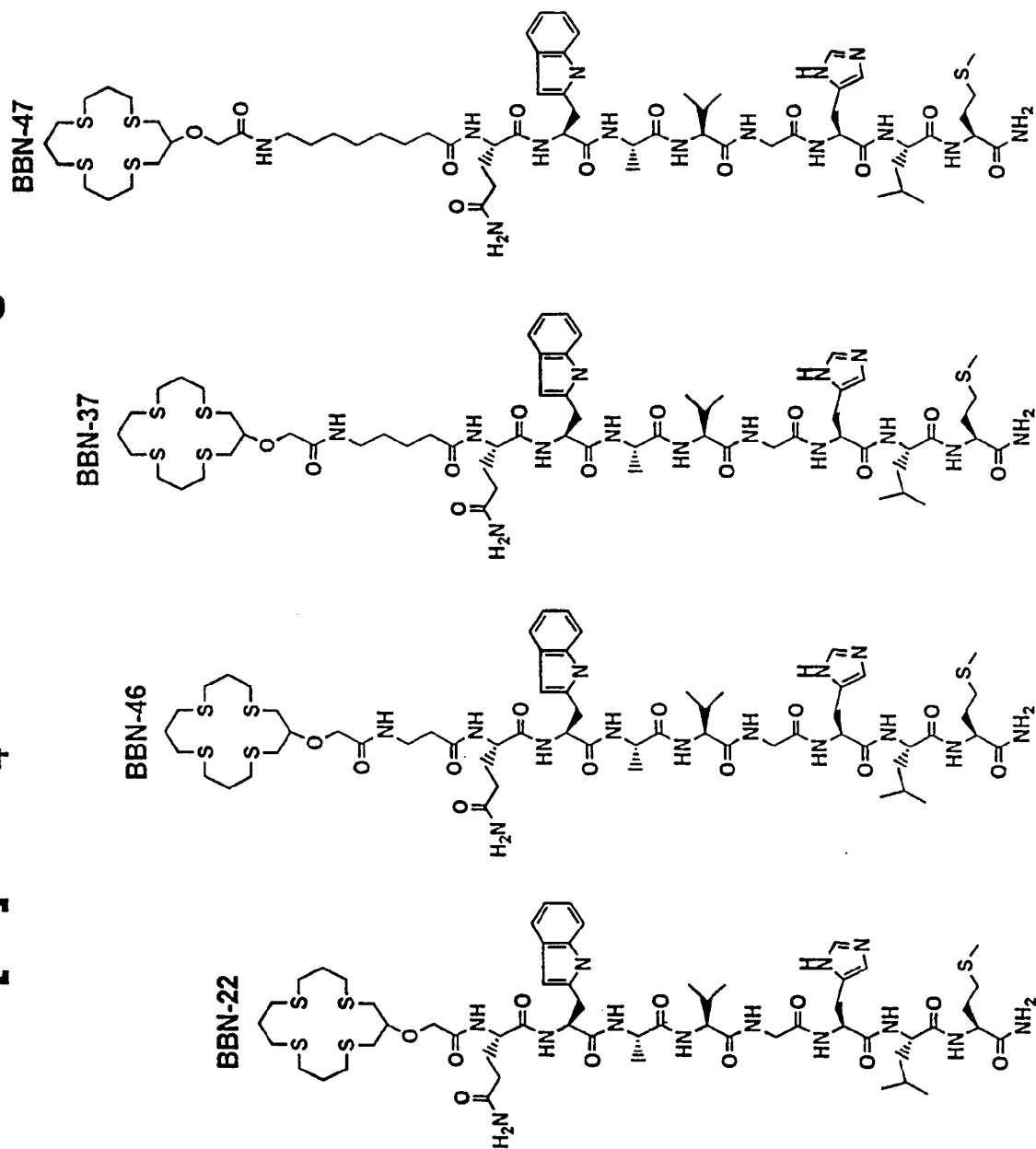
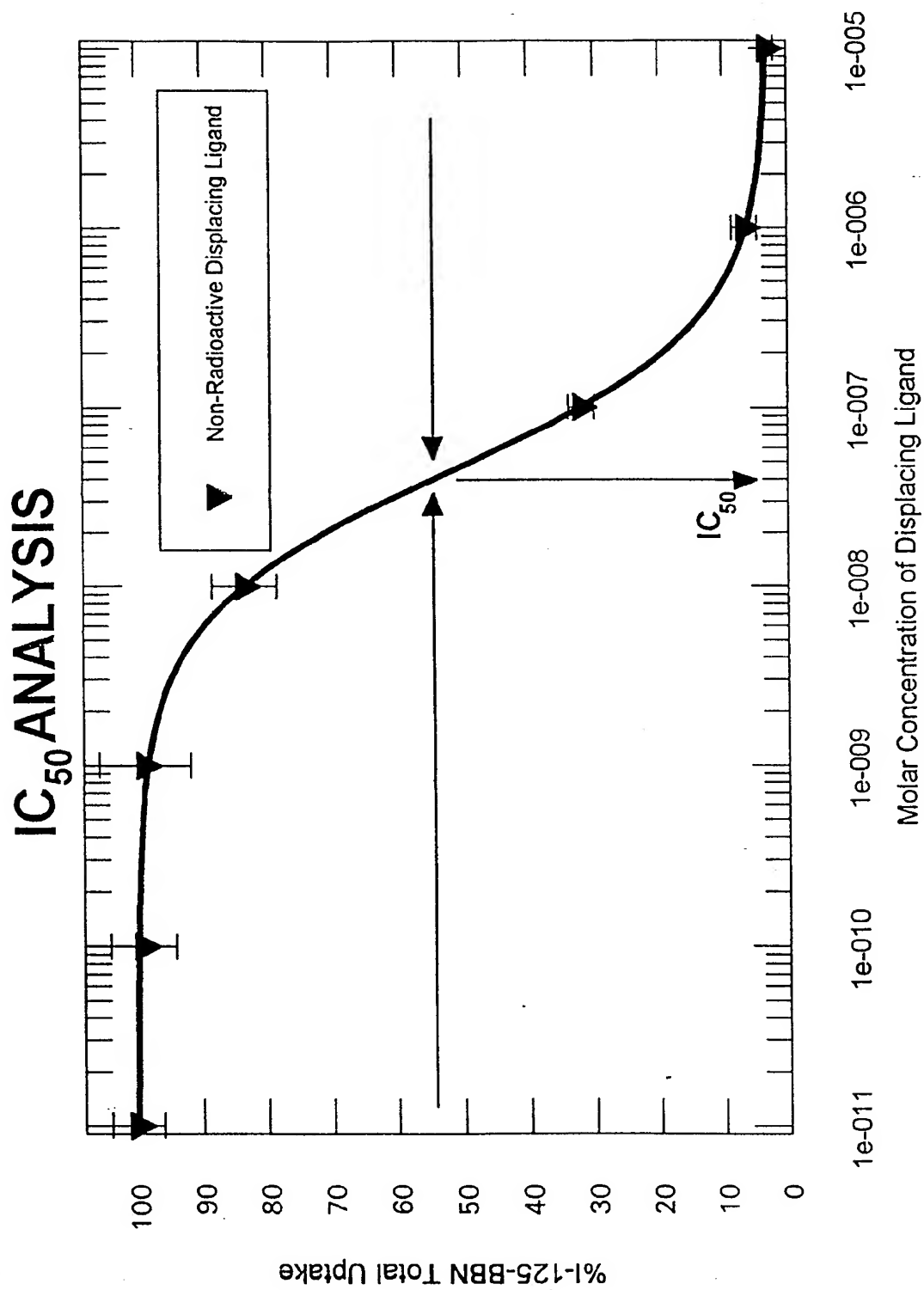


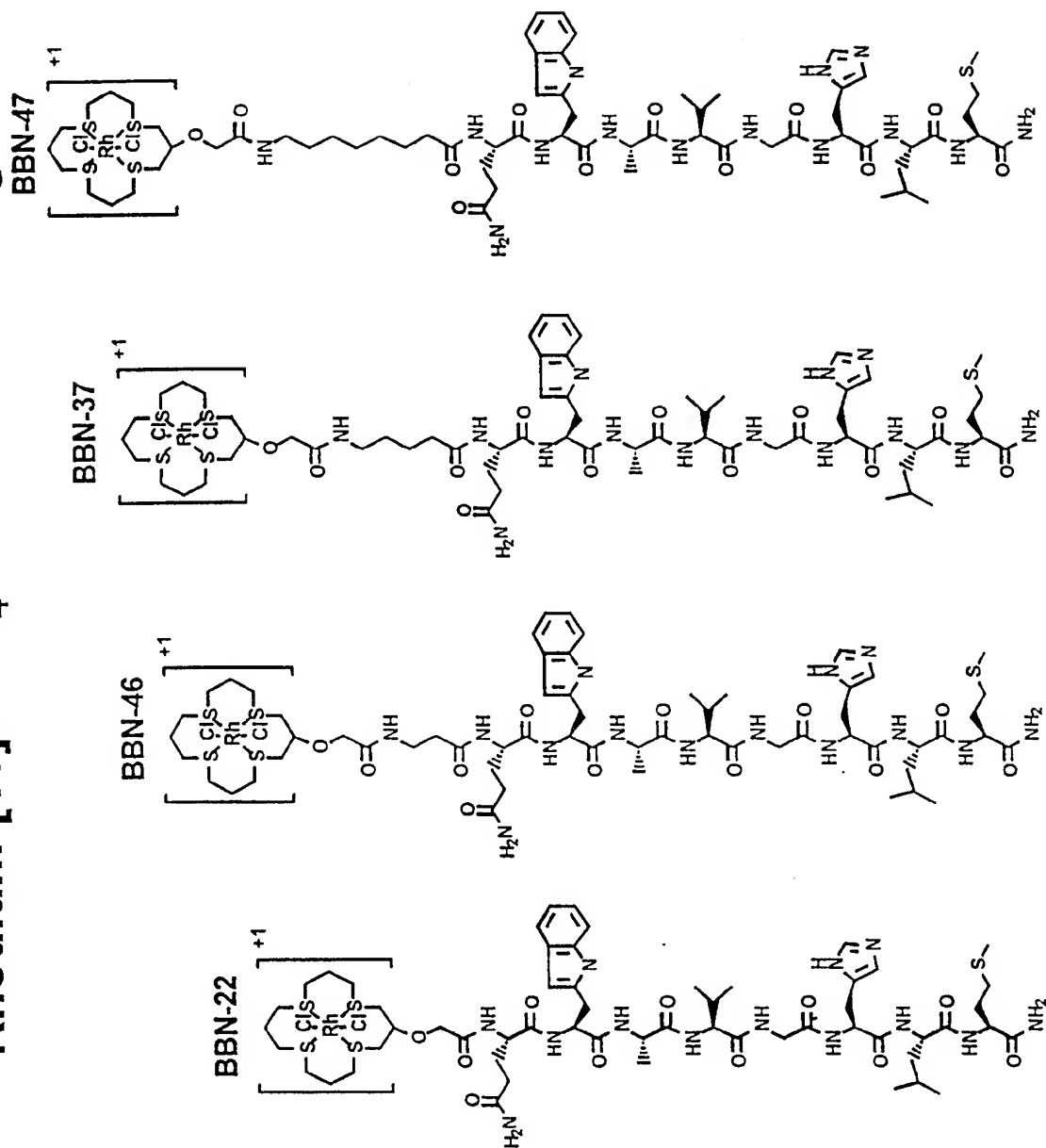
Figure 7

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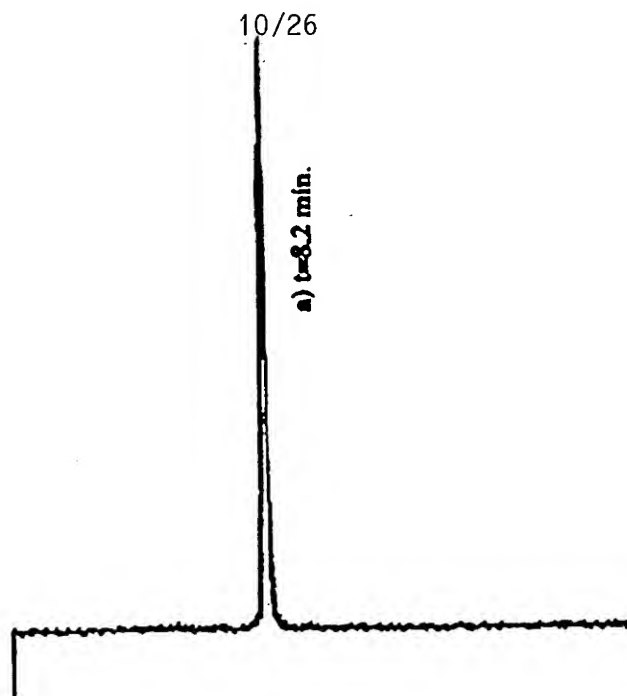
Figure 8

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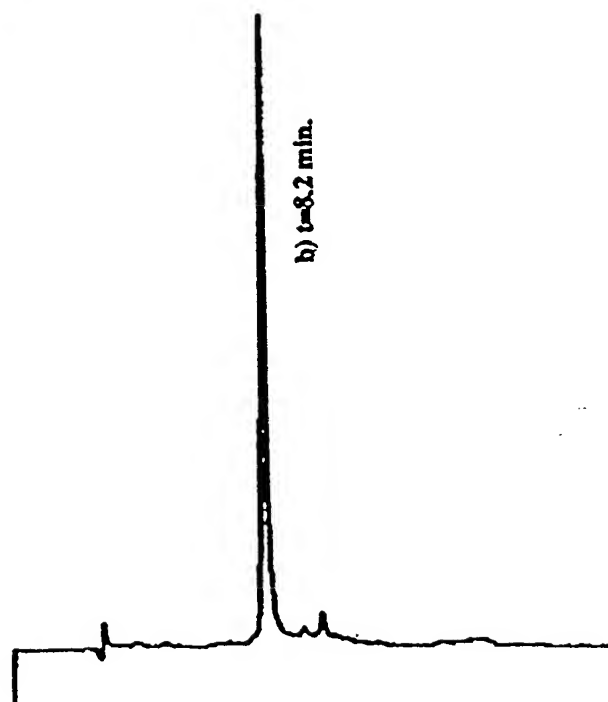
Rhodium-[16]aneS₄ Bombesin Analogues



A.



B.



HPLC Chromatogram of Rhodium-BBN-37
Top: $^{105}\text{RhCl}_2\text{-BBN-37}$
Bottom: $\text{RhCl}_2\text{-BBN-37}$

Figure 10

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^{125}I -Tyr⁴-Bombesin Internalization Efflux in ^{125}I -Tyr⁴-BBN Free Buffer

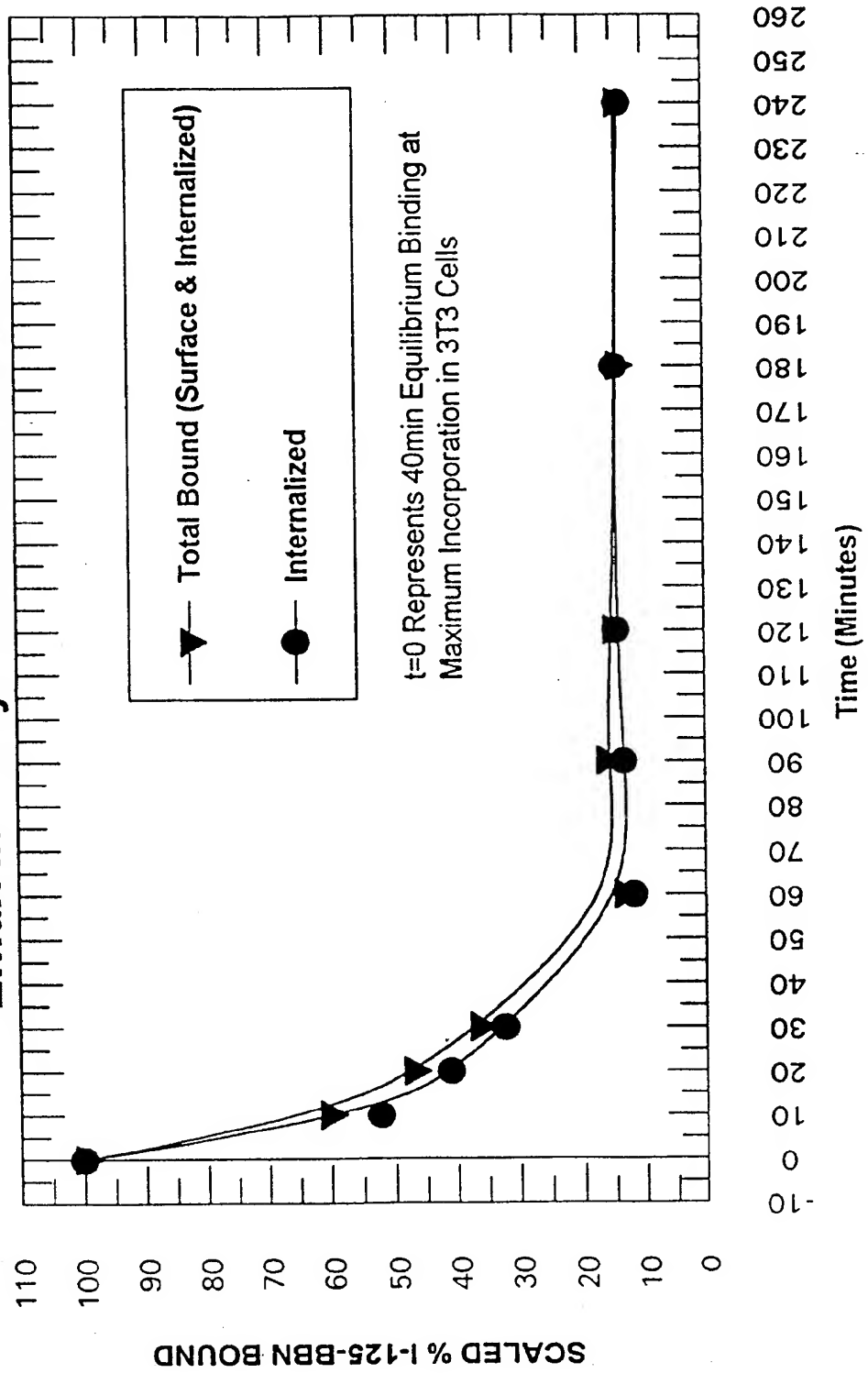
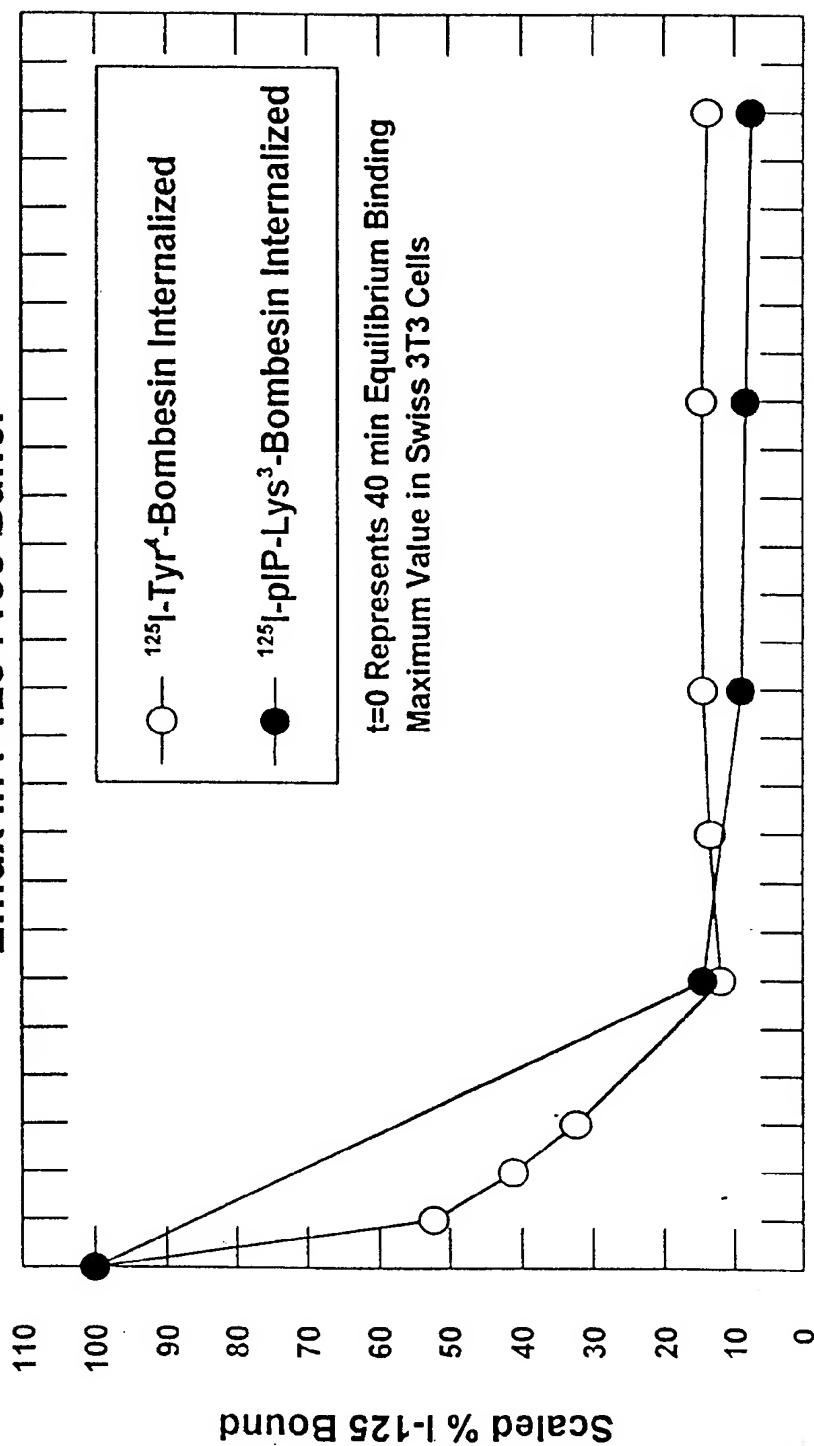


Figure 11

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I-125 Bombesin Internalization

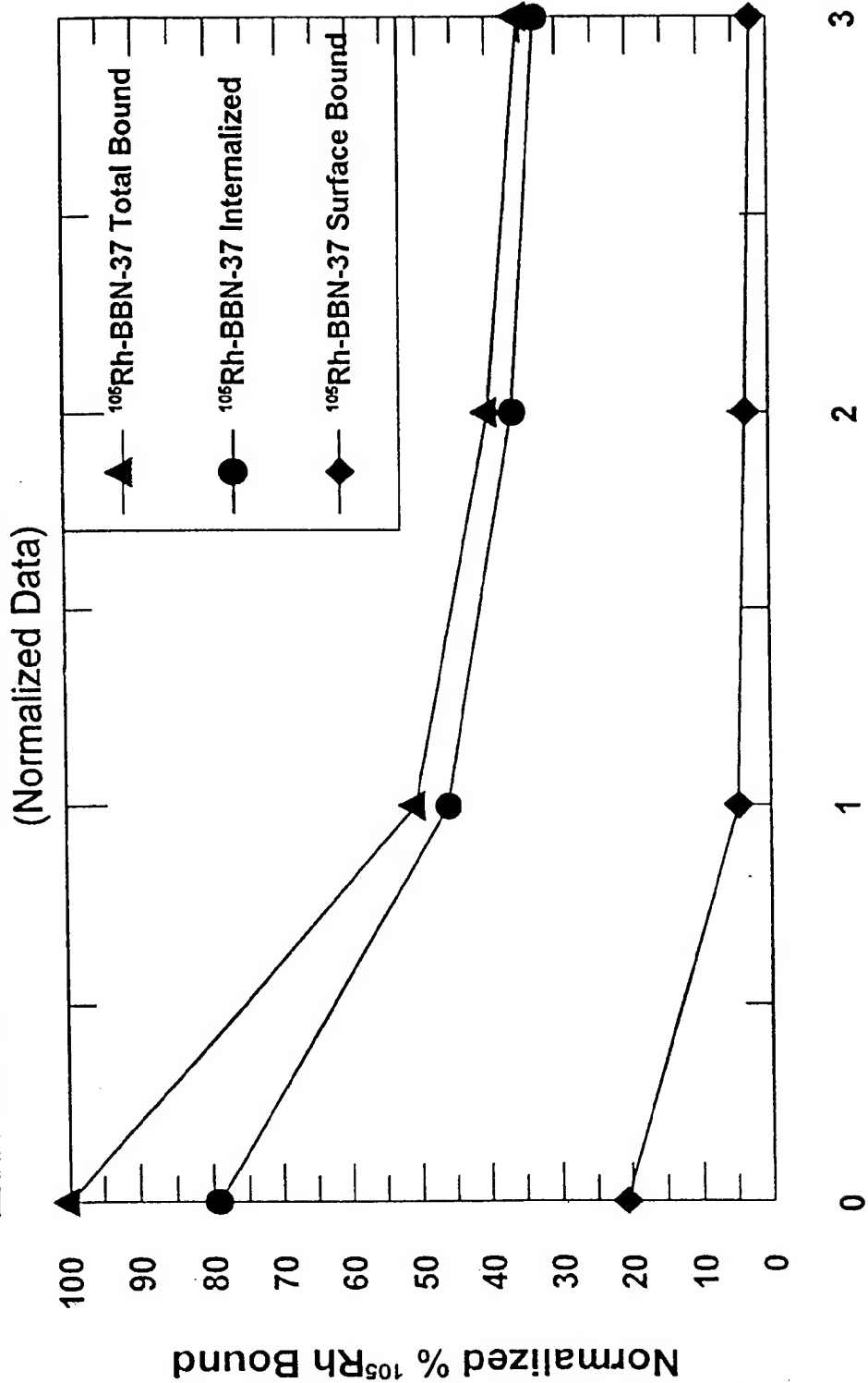
Efflux in I-125 Free Buffer



Time (Minutes)

Figure 12

Efflux of ^{105}Rh -BBN-37 in Swiss 3T3 Cells



Time (Hours)
Figure 13

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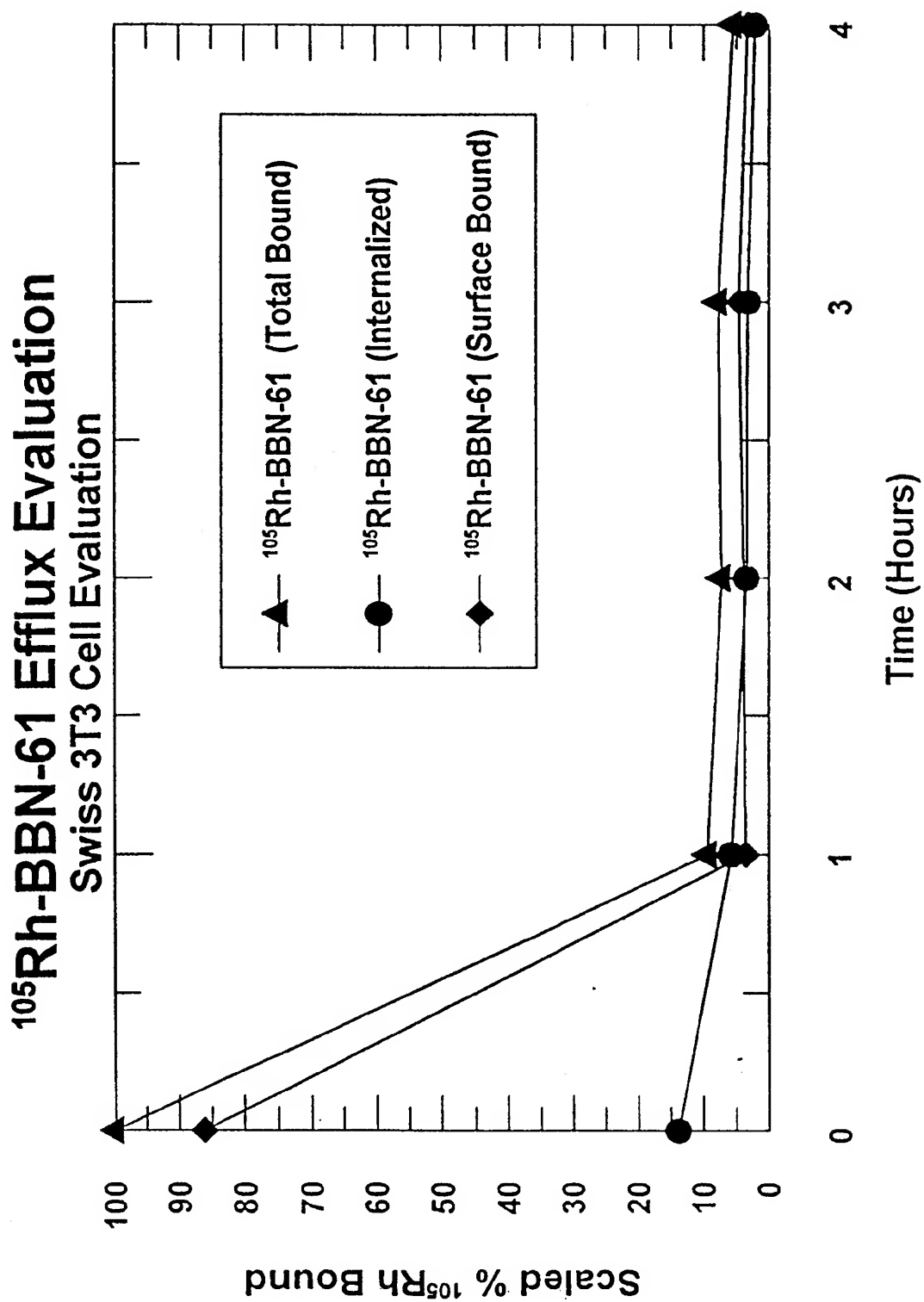


Figure 15

Efflux of ^{105}Rh -BBN-22 vs. ^{105}Rh -BBN-37 in Swiss 3T3 Cells (Non-Normalized Data)

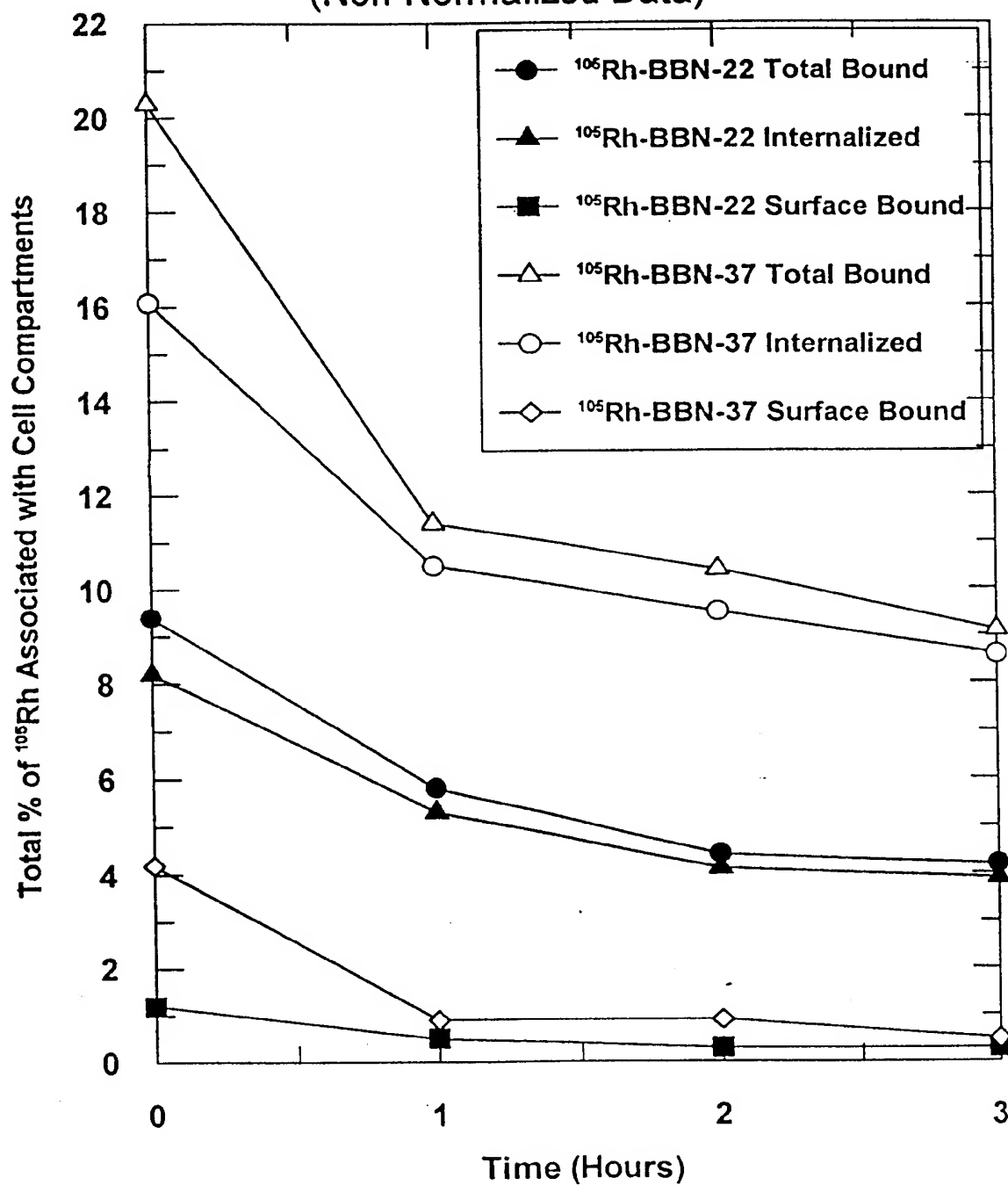
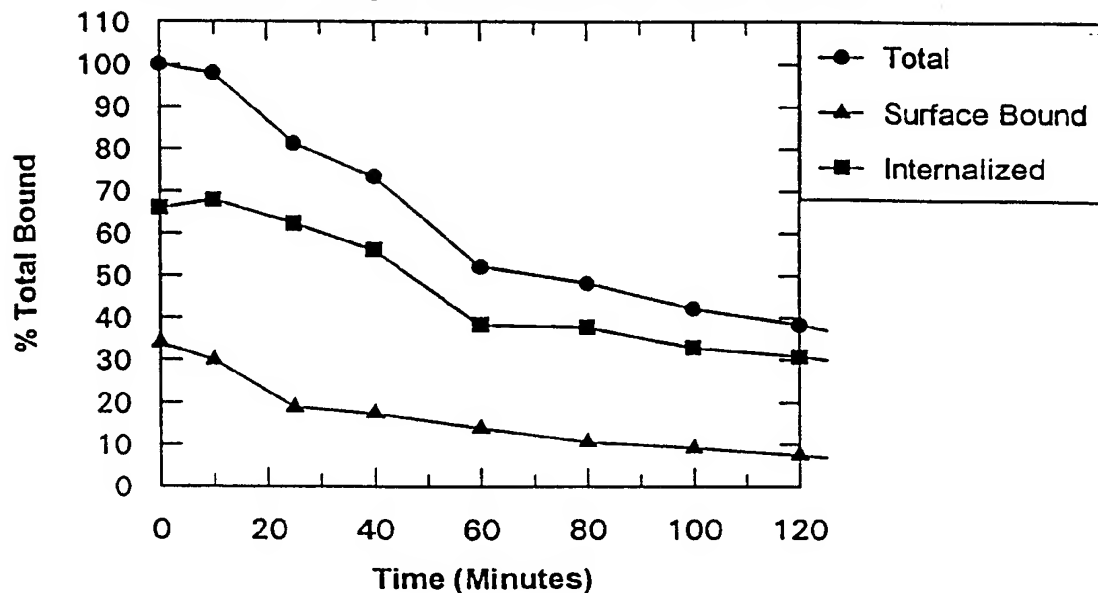


Figure 16

Pancreatic CA Cell Binding

A.

Efflux of ^{125}I -Tyr⁴-BBN from CF PAC1 Cells



B.

Efflux of ^{105}Rh -BBN-37 from CF PAC1 Cells

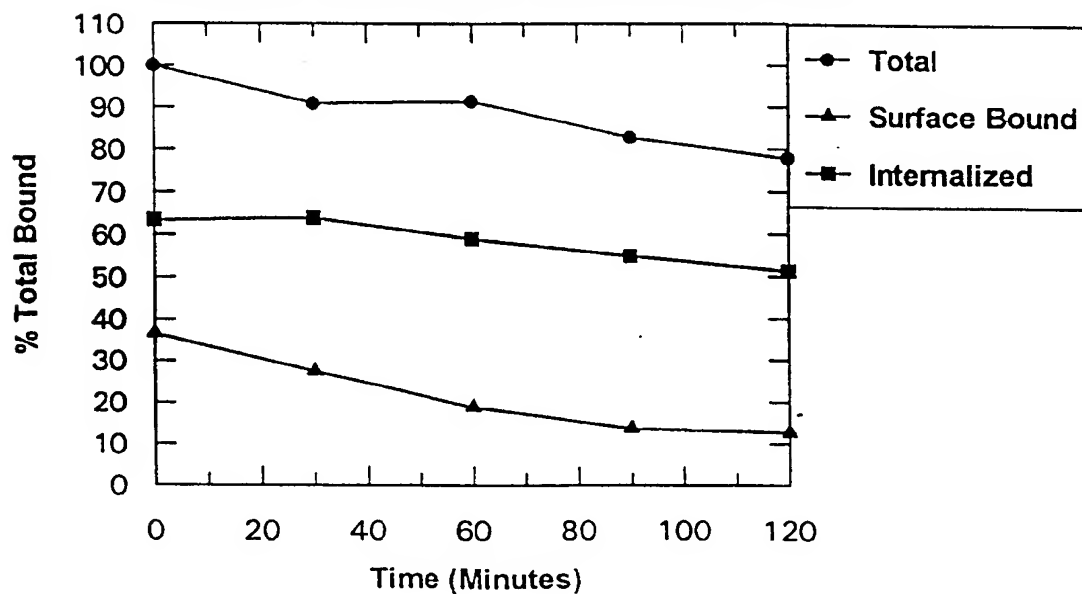
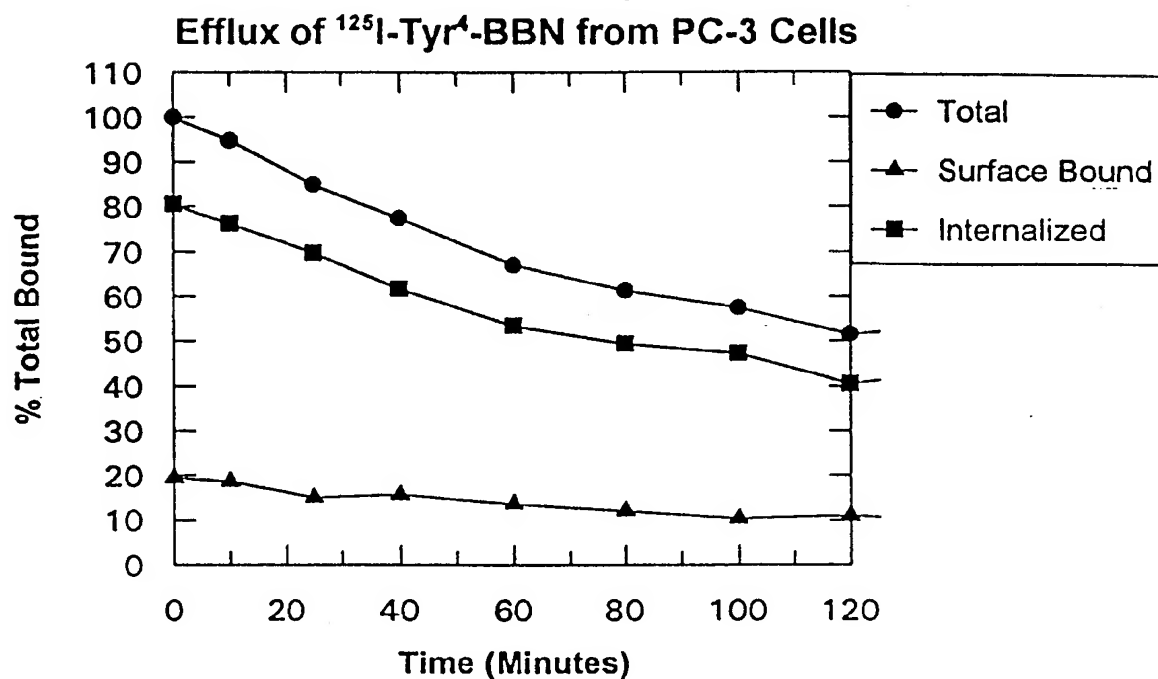


Figure 17

Prostate CA Cell Binding

A.



B.

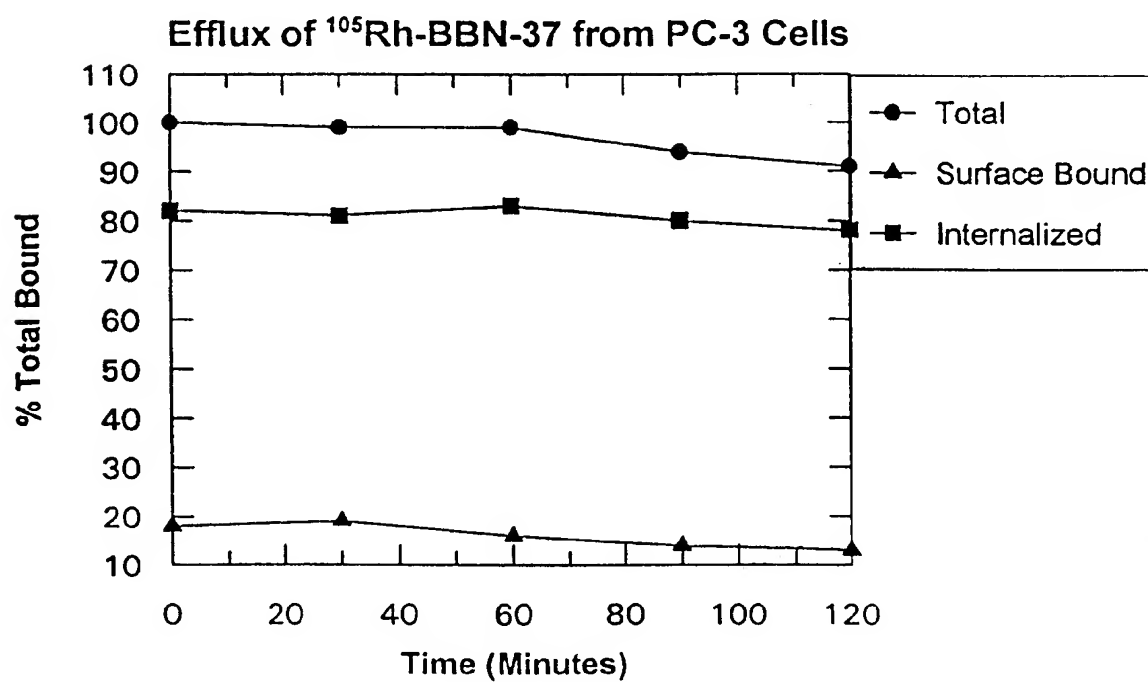


Figure 18

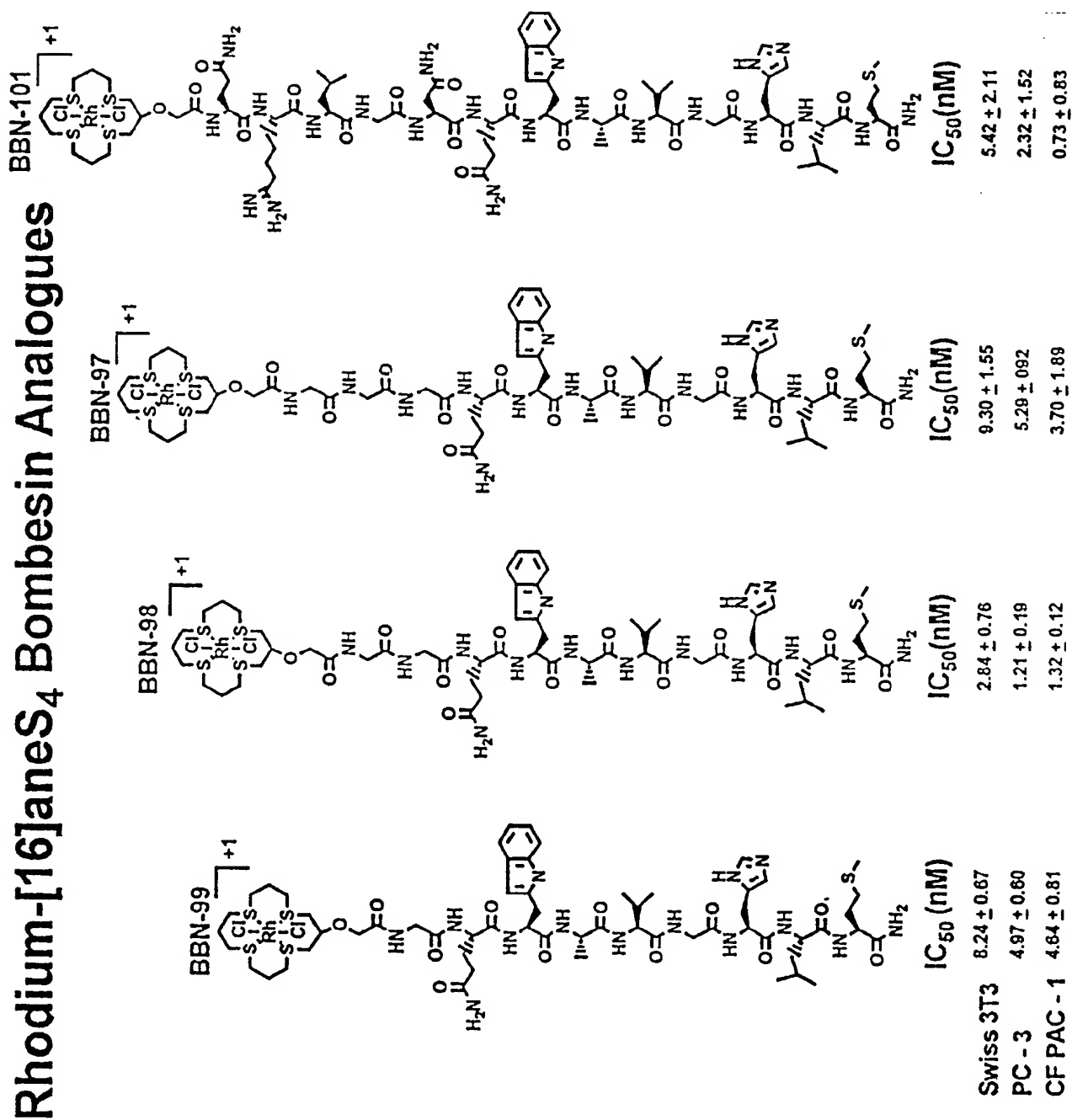


FIGURE 20

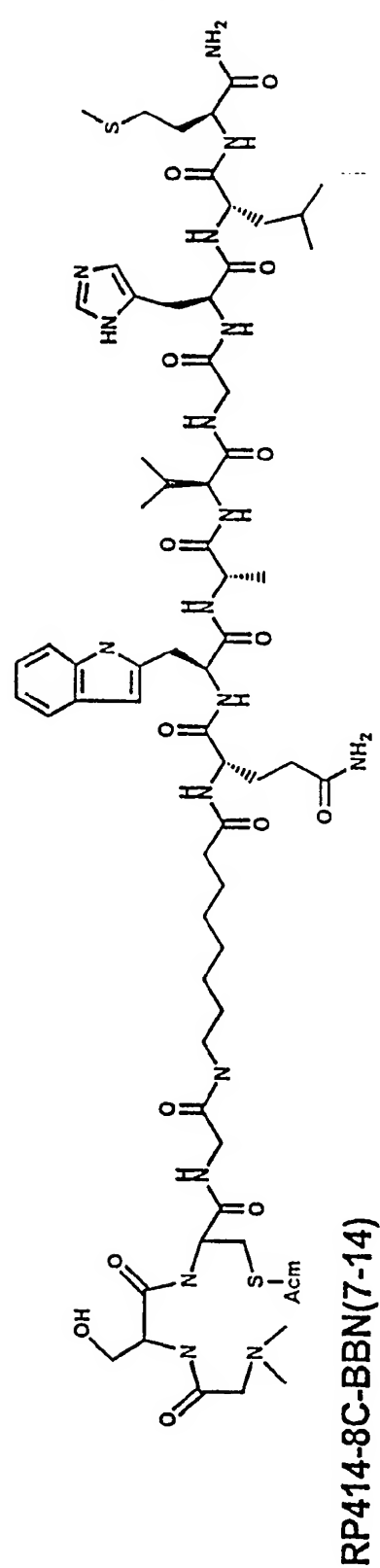
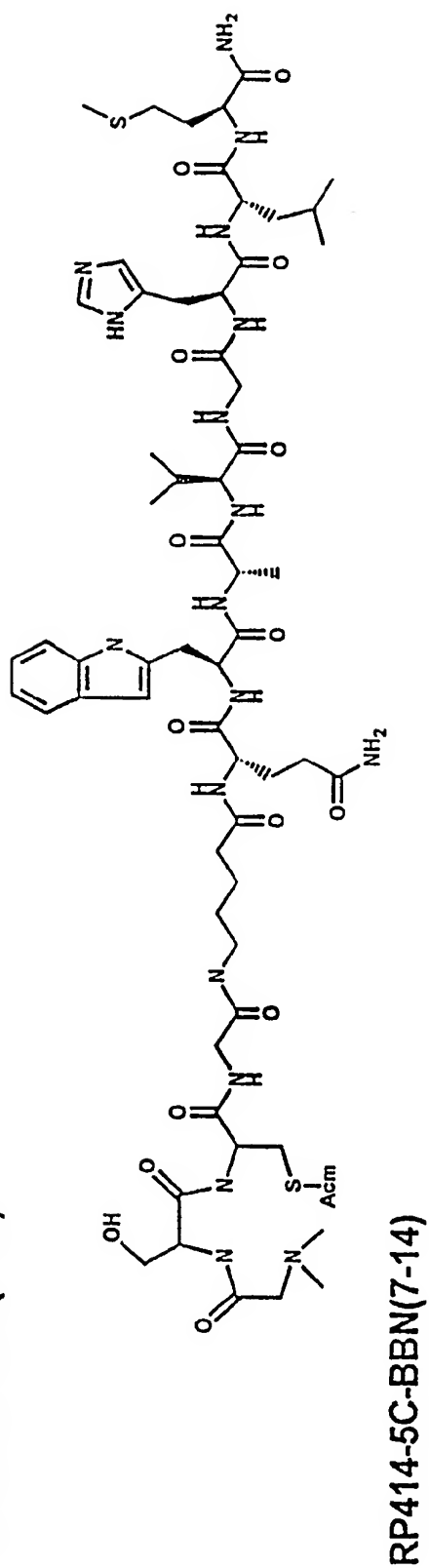
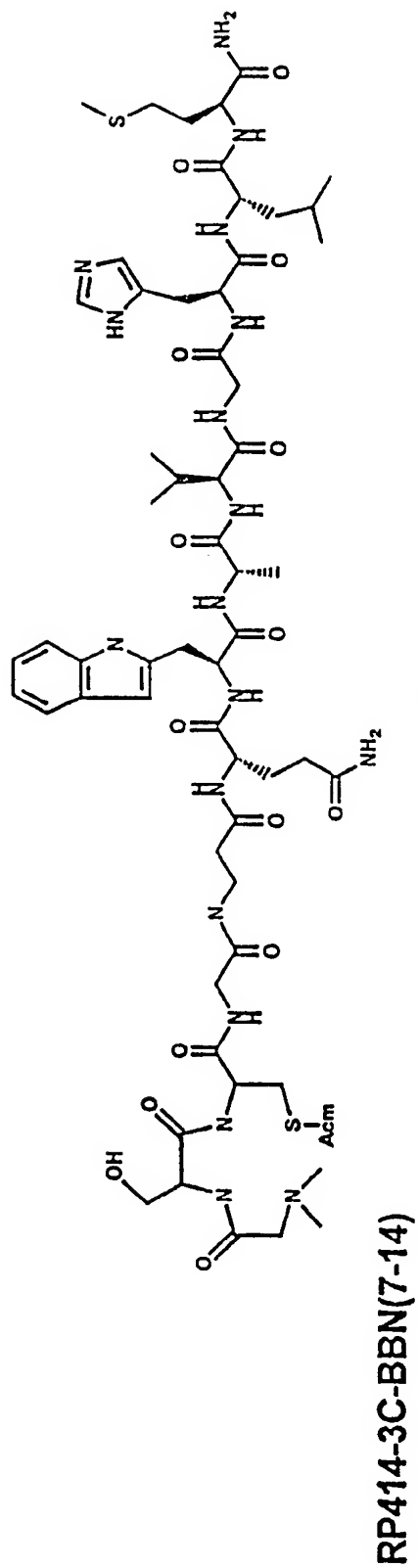
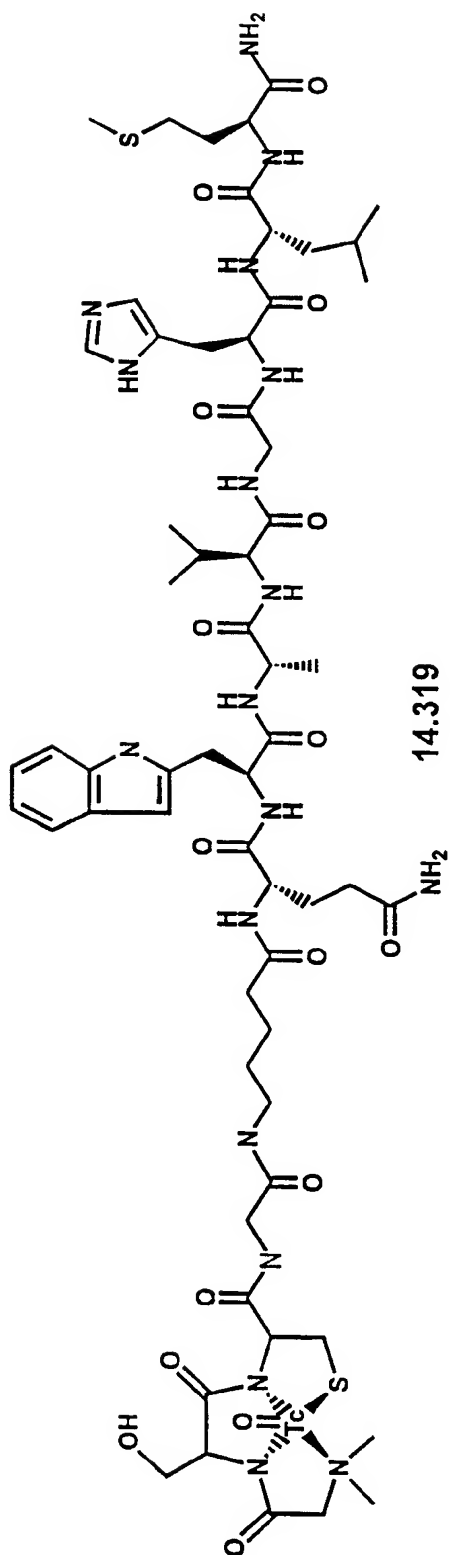


FIGURE 21

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^{99m}Tc-BBN-122

14.319

HPLC Gradient Elution Program

Flow 1.5 ml/min

Solvent A = H₂O with 0.1% TFASolvent B = CH₃CN with 0.1% TFA

Time(min)	%A/%B
0	95/5
25	30/70
30	95/5



Figure 22

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^{99m}Tc-BBN-122 Uptake in Human Prostate Cancer Cells

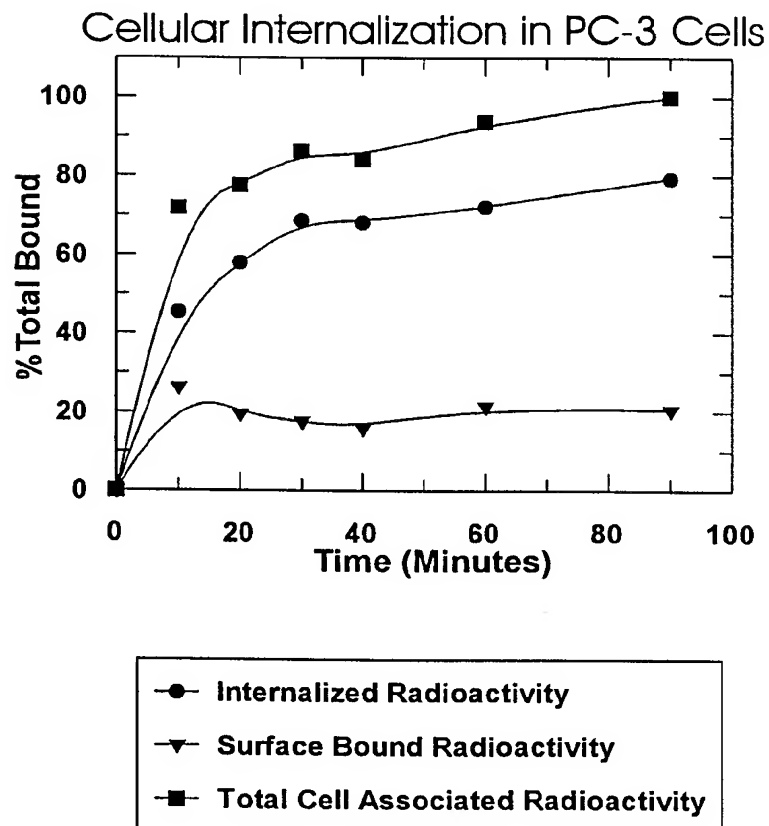


Figure 23

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^{99m}Tc-BBN-122 Internalization in Human Pancreatic Cancer Cells

Cellular Internalization in CFPAC-1 Cells

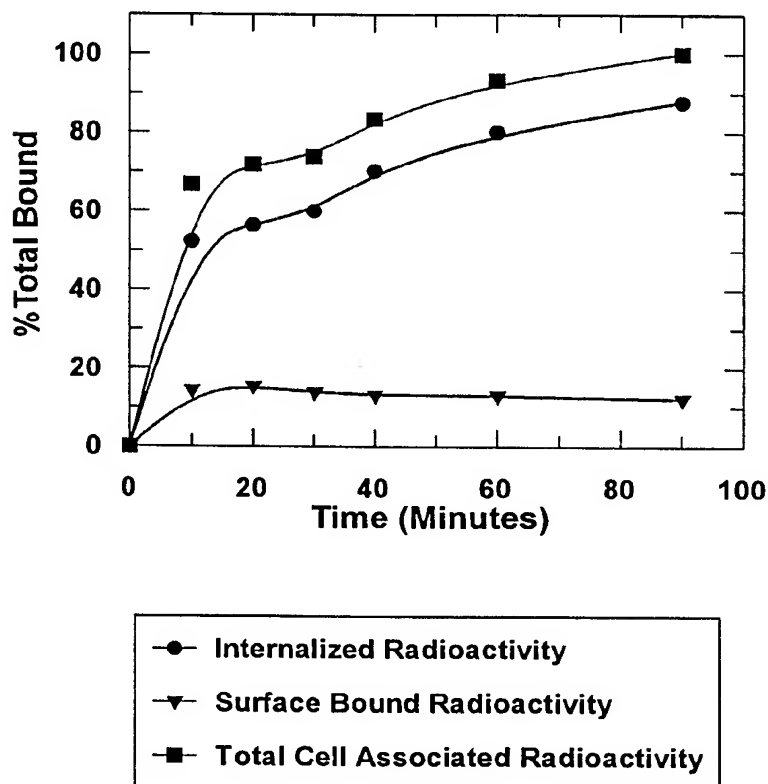


Figure 24

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^{99m}Tc-BBN-122 Retention in Human Prostate Cancer Cells

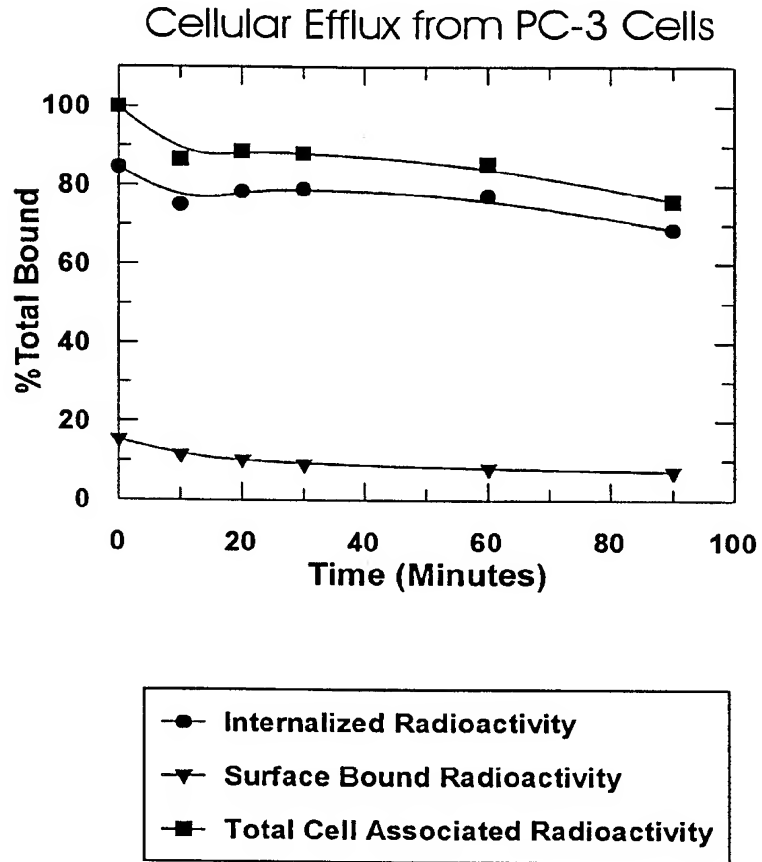


Figure 25

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^{99m}Tc-BBN-122 Retention in Human Pancreatic Cancer Cells

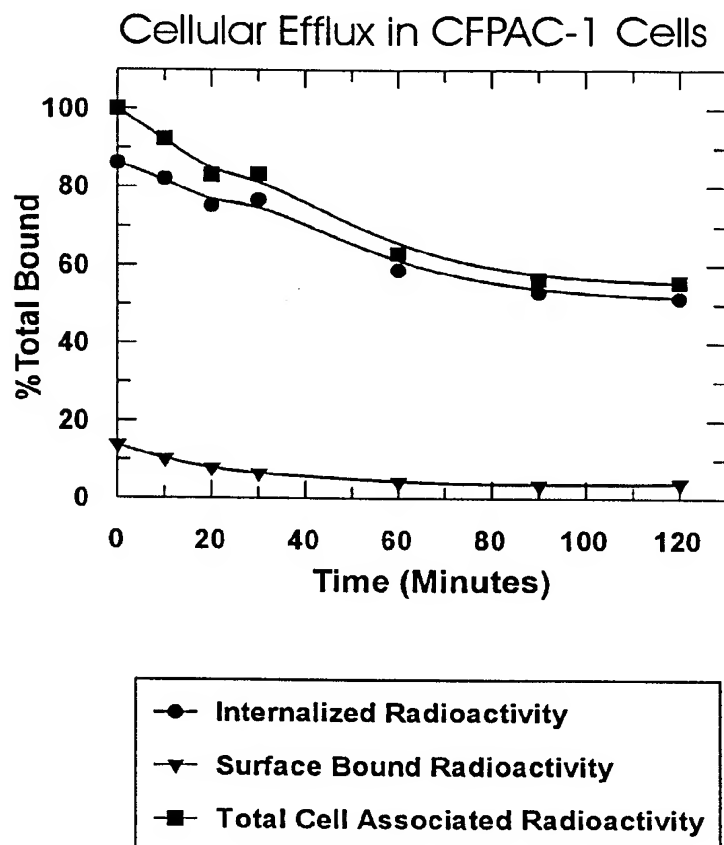


Figure 26

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US98/07990

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :A61K 38/08, 38/10; C07K 7/06, 7/10

US CL :514/14, 15, 16; 530/326, 327, 328

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 514/14, 15, 16; 530/326, 327, 328

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CAS ON LINE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,620,995 A (KNIGHT et al.) 15 April 1997, columns 5-10.	1-85
A	US 5,534,497 A (VERBRUGGEN) 09 June 1996, columns 1-4.	1-9
A	US 5,620,959 A (LEBAN et al.) 15 April 1997, columns 2-6.	1-85
A	US 5,369,094 A (SCHALLY et al.) 29 November 1994, columns 2-6.	1-85
A	US 5,244,883 A (CAI et al.) 14 September 1993, columns 1-8.	1-85
A	US 5,217,955 A (BOGDEN et al.) 08 June 1993, columns 1-10.	1-85



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	* T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
* A* document defining the general state of the art which is not considered to be of particular relevance	* X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
* E* earlier document published on or after the international filing date	* Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
* L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	* A* document member of the same patent family
* O* document referring to an oral disclosure, use, exhibition or other means	
* P* document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

29 JULY 1998

Date of mailing of the international search report

28 SEP 1998

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